User Guide

HypoSensor
Force Balance Accelerometer
Model FBA ES-DH

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FerriShield

Microsoft Windows

Kinemetrics, Inc., 222 Vista Avenue, Pasadena, CA 91107 USA

Phone: (626) 795-2220 ■ Fax: (626) 795-0868

E-mail: services@kmi.com

Website: www.kinemetrics.com

Kinemetrics SA, Le Tresi 3, 1028 Preverenges, Switzerland

Phone: 21.803.2829 ■ Fax: 21.803.2895

E-mail: kmi_sa@bluewin.ch

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Safety

Symbols & Terms

The following symbols may appear on Kinemetrics equipment or in this manual.

When you see this symbol, *pay careful attention.* Refer to the similarly marked, relevant part of this manual before servicing the instrument.

This symbol means a *low-noise earth ground*. The noted item should be grounded to ensure low-noise operation, and also to serve as a ground return for EMI/RFI and transients. Such a ground *does not work as a safety ground* for protection against electrical shock!

~ This symbol means an alternating current (AC) power line.

This symbol means a direct current (DC) power line derived from an AC power line.

This symbol indicates an electrostatic sensitive device (ESD), meaning that when handling the marked equipment you should observe all standard precautions for handling such devices.

These safety-related terms appear in this manual:

Note: statements identify information that you should consider before moving to the next instruction or choice.

Caution statements identify conditions or practices that could result in damage to the equipment, the software, or other property**.**

WARNING! statements identify conditions or practices that could result in personal injury or loss of life.

Specific Precautions

Follow the precautions below to ensure your personal safety and prevent damage to the HypoSensor.

Power Source

The HypoSensor must be supplied with power either from a recorder or from a customer-supplied ± 12V or ± 15V power supply (or a + 12V supply for the single-supply option).

If you plan to power the HypoSensor from a recorder, connect the recorder to a power supply/charger supplied by Kinemetrics, as described in each recorder's user manual.

To supply power directly to the HypoSensor, you need a low-noise, regulated ± 12V or ± 15V power supply (or a + 12V supply for the single-supply option) that is safely grounded and meets all applicable local regulations. The HypoSensor will be damaged if the power is connected with the wrong polarity.

User-Supplied Power/Charging System

If you supply your own power/charging system, be sure that the system provides the correct voltage and current required by the HypoSensor under all operating conditions. You are responsible for the safety of your charging system. If you get power from the mains supply, be sure you have supplied adequate grounding for all the equipment. If you supply your own batteries, follow the manufacturer's safety recommendations.

Sensor Grounding and Cabling

In some cases the HypoSensor will be a long distance from the recorder. In these installations it is possible, due either to faulty AC wiring or extremely high earth-return currents, for a high potential difference to exist between the grounds at the two locations. When the cable is grounded at one end a potentially lethal voltage can exist between the other end of the cable and ground. Consider this danger during installation and get help from a qualified electrician if this danger exists.

Do Not Operate in Explosive Atmosphere

The HypoSensor provides *no explosive protection* from static discharges or arcing components. *Do not* operate the equipment in an atmosphere where explosive gases are present.

Sicherheit

Symbole & Begriffe

Diese *Symbole* können auf Kinemetrics Geräte oder in diesen Manuel erscheinen:

Bedeutet *Achtung*! Wenn sie dieses Symbol auf ein Gerät sehen, muss den gleich markierten Teil dieses Manuels beachet werden. *Bevor* irgend eine Unterhaltsarbeit angefangen wird, *muss* dieser Teil des Manuels gelesen werden. Wenn Sie dieses Symbol sehen, bitte besondere Achtung geben.

Bedeutet Erdung. Das erwaente Teil sollte geerdet werden, um eine "low-noise" operation zu versichern, und dann auch als Erdung für EMI/ FRI und Transienten und solch eine Erdung wird *nicht als Sicherheit gegen* elektrischen Schock dienen!

~ Bedeutet *Wechselstromzufuhr* (AC) mit Elektroschock Gefahr.

⎓ Bedeutet Gleichstromzufuhr von AC Versorgung herkommend.

Bedeutet *Elektrostatisch Sensibeles Element (ESD)* für dessen Handhabung alle vorbeugende Vorsichtsmassnahmen genommen werden müssen.

Folgende *Darstellungen* werden in diesen Manuel erscheinen:

Note: Darstellung welche Informationen Sie erhalten, die besonders beachtet werden müssen, bevor sie zum nächsten Schritt gehen.

Caution: Darstellung bei dem die Missachtung in der Regel Gefahr für Defekte und Störungen im Gerät, Programm oder Zubehör besteht.

WARNING! Darstellung bei dem die Missachtung in der Regel Verletzungs – oder Lebensgefahr besteht.

Spezielle vorbeugende Massnahmen

Alle vorbeugende Massnahmen müssen beachtet werden. Für Ihre persönliche Sicherheit, und um Schäden im HypoSensor zu vermeiden.

Stromversorgung

Die HypoSensor muss entweder mit Strom von einem Accelerograph oder Ihrer eigenen Stromquelle ±12 V versorgt werden.

Sollten Sie planen, die HypoSensor mit Strom von einem Recorder zu versorgen, verbinden Sie den Recorder mit unserem Kinemetrics Stromladegerät, wie es in unserem “User Manuel” beschrieben ist.

Um die HypoSensor direkt mit Strom zu versorgen, müssen Sie ein Ladegerät ±12 V, welches mit allen Sicherheitsbedingunge ausgestattet ist, benutzen.

Optionelles Stromversorgungs/Ladegerät

In manchen Fällen wird die HypoSensor eine lange Strecke von dem Recorder entfernt Sein, wo es dann möglich sein könnte, dass durch beschädigte AC-Wiring oder Hohe Erdbewegungen, ein Spannungsunterschied besteht. Es ist daher unbedingt notwendig, dass alle angeschlossenen Instrumente am gleichen Spannungspotential geerdet sind. Bitte folgen Sie den vom Hersteller gegebenen Empfehlungen.

Verkablung und Erdung vom Sensor

Wenn das Kabel an einem End geerdet ist, kann ein verhältnismässig grosser Unterschied in der Voltage bestehen, welcher sehr gefährlich ist. Bitte beachten Sie Diese Gefahr und wenn nötig, ziehen Sie das Gutachten eines qualifizierten Elektrikers Ein.

Nicht in explosionsgefährdete Umgebung gebrauchen

Der HypoSensor hat keinen Explosions-schutz von statischen Entladungen oder funkgefährdeten Bauteilen. Benutzen sie die Geräte nicht in Umgebungen mit explosiven Gasen.

Seguridad

Símbolos & Términos

Estos *símbolos* podrían aparecer en los equipos Kinemetrics o en este manual:

Significa *poner atencion!* Cuando Usted vea este símbolo en el instrumento, referirse a las partes de este manual marcadas similarmente. *Antes* de intentar cualquier servicio en este instrumento, Usted *tiene que* leer las partes relevantes de este manual. Si Usted ve este símbolo, ponga atención cuidadosamente.

Significa un *polo a tierra de bajo ruido*. El ítem referido debe estar polarizado a tierra para asegurar la operación a bajo ruido y además sirve como un retorno a tierra para el EMI/RFI y transitorios. Tal polo a tierra no trabaja como un polo a tierra de seguridad para protección contra choques eléctricos!

~ Significa una línea de energía de Corriente Alterna (AC).

Significa una línea de energía de Corriente Directa derivada de una línea de energía AC.

Significa una *Unidad Sensitiva a Electrostática* (*Electrostatic Sensitive Device* ESD), indicando que usted debe tener cuidado y observar todas las precauciones para el manejo de tales unidades.

Estos *términos* aparecerán en este manual:

Note: sentencias identificando información que Usted debe considerar cuidadosamente antes de dirigirse a la siguiente instrucción u opción.

Caution: sentencias identificando condiciones o practicas que podrían resultar en daño del equipo, el software u otra propiedad.

WARNING! sentencias identificando condiciones o practicas que podrían resultar en una lesión personal o la perdida de la vida.

Los últimos dos términos mencionados arriba podrían también aparecer en el equipo Kinemetrics que Usted ha comprado, pero no necesariamente — indiferentemente, Usted debe definitivamente tomar notas serias de las precauciones y advertencias en este manual.

Precauciones Específicas

Siga las precauciones a continuación para garantizar su seguridad personal y prevenir daños al HypoSensor.

Fuente del poder

El HypoSensor debe ser alimentado con energía ya sea desde un registrador o desde una fuente de ± 12V provista por el usuario.

Si usted planea alimentar el HypoSensor desde un registrador, conecte el registrador a una fuente de poder/cargador suministrado por Kinemetrics, como se describe en cada manual del usuario para el registrador.

Para suministrar energía directamente al HypoSensor, usted necesita una fuente de poder de bajo ruido y regulado ± 12V, el cual debe ser apropiadamente conectado a tierra y cumplir con todas las regulaciones locales que apliquen.

Sistema de Poder/Carga Provisto por el Usuario

Si usted provee su propio sistema de poder/carga, usted tiene que estar seguro, que el sistema proporciona el voltaje correcto y la corriente requerida por el HypoSensor bajo todo las condiciones de operación. Usted es responsable por la seguridad de su sistema de carga.

Si usted deriva energía de suministro principal, usted tiene que asegurarse que ha provisto un polo a tierra adecuado para todo el equipo. Si usted suministra sus propias baterías, siga las recomendaciones de seguridad del fabricante.

Cableado y Polo a Tierra del Sensor

En algunos casos el HypoSensor estará a una distancia lejos del registrador. En estas instalaciones existe la posibilidad de una elevada diferencia de potencial entre dos localidades de polo a tierra, debido ya sea a fallas en el alambrado del AC o corrientes de un extremadamente alto retorno de tierra. Cuando el cable esta polarizado a tierra en uno de sus lados terminales, un voltaje potencialmente letal puede existir entre el otro lado terminal del cable y el polo a tierra. Considere este peligro durante la instalación y obtenga ayuda de un electricista calificado si este peligro existe.

No Opere en Atmósferas Explosivas

El HypoSensor no proporciona *ninguna protección explosiva* para descargas estáticas componentes que generen arcos eléctricos. *No operar* el equipo en una atmósfera de gases explosivos.

Sécurité

Symboles & Terminologie

Les *symboles* suivant peuvent figurer sur les équipements Kinemetrics ou dans ce manuel:

Signifie *Attention!* Quand vous rencontrez ce symbole sur un instrument, veuillez vous référer à la section de ce manuel signalée par la même marque. *Avant* même d'effectuer la première opération sur l'instrument, vous devez lire la section correspondante de ce manuel. Faite attention si vous voyez cet symbole.

Indique une mise à la terre "faible bruit". Les objets portant cette marque doivent être reliés à la terre afin d'assurer un fonctionnement optimal. Elle est aussi utilisée pour les éléments de protection contre les interférences magnétiques, les perturbations hautes fréquences radio et contre les surtensions. Cette mise à terre *n'est pas une mise à terre de sécurité* pour une protection contre les choques électriques!

~ Indique une *alimentation en courant alternatif* (AC).

⎓ Indique une Alimentation en courant continu (DC) dérivée d'une alimentation alternative

Indique la présence *d'un composant sensible aux décharges électrostatiques* (ESD), Cela signifie qu'il faut observer toutes les précautions d'usage en manipulant ce composant.

Les *termes* suivant apparaissent dans ce manuel:

Note: Indique la présence d'une information que vous devez particulièrement considérer avant de passer à la prochaine instruction or operation.

Caution: Indique une condition ou opération qui peut entraîner des dommages à votre équipement, au logiciel ou à d'autres propriétés .

WARNING! Indique une condition ou opération qui peut entraîner des blessures corporelles ou la perte de la vie.

Les deux derniers termes mentionnés peuvent apparaître sur les équipements de Kinemetrics que vous avez acquis, mais pas nécessairement — indifféremment, il est conseillé de prendre au sérieux les avertissements de ce manuel.

Précautions Spécifiques

Observez toutes les précautions suivantes afin d'assurer votre sécurité personnelle et d'éviter des dégâts aux composants de votre capteur HypoSensor.

Alimentation

Le HypoSensor doit être alimenté avec un courant de ±12 VDC fourni par l'enregistreur ou par votre propre système d'alimentation.

Si vous alimentez le HypoSensor avec l'enregistreur, connectez l'enregistreur en utilisant le système d'alimentation fourni par Kinemetrics, et decrit dans le manuel d'utilisation délivré avec l'enregistreur.

Pour fournir une alimentation au HypoSensor, vous avez besoin d'une source à faible bruit ± 12V avec une mise a la terre adéquate et qui remplit les conditions de la reglementation locale.

Option Systéme d' alimentation fourni par l'utilisateur

Si vous fournissez votre système d'alimentation, vous devez vous assurez que le système fournit une tension et un courant requis par le HypoSensor. Veuillez noter que vous serez seul responsible pour la sécurité de votre système d'alimentation. Si vous utilisez le courant du réseau d'alimentation principal, vous devez vous assurez d'installer les mises a la terre adéquates pour tout votre equipement. Si vous utilisez vos batteries, vous devez vous référer aux recommendations fournis par le fournisseurs.

Mise à la terre et connection du capteur

Dans certain cas, le capteur HypoSensor est installé à distance de l'enregistreur. Dans ces installations il est possible, soit a cause d'une connection défectueuse au système d'alimentation principale où d'un fort courant de retour à la terre, pour une difference de potentiel qui existe entre la mise à la terre aux deux locations. Quand le cable est mise à la terre d'un coté, une tension potentiellement fatale peut exister entre l'autre coté du cable et la terre. Considerez ce danger pendant l'installation et demandez l'aide d'un electricien si ce danger existe.

Ne Pas Utiliser en Atmosphère Explosif

Le HypoSensor ne comprend pas de protection contre les explosions dues aux décharges statiques ou aux composants pouvant provoquer des arcs. Ne pas utiliser ces composants en présence de gaz explosifs.

1. Introduction

The *User's Guide to the HypoSensor* contains the information necessary to operate and install the HypoSensor triaxial borehole seismic sensor. Kinemetrics also produces a triaxial EpiSensor FBA ES-T, a uniaxial EpiSensor FBA ES-U, and the FBA ES-SB (shallow borehole). Kinemetrics' strong motion accelerographs feature a triaxial EpiSensor Altus deck.

Kinemetrics is committed to ensuring a successful installation. For assistance with planning, installation, operation or maintenance, contact us at the locations listed in the front of this manual. We also have an extensive Services Group that can install, maintain, and analyze the data from your HypoSensor.

This chapter provides an overview of the HypoSensor and inspection instructions.

The HypoSensor

The HypoSensor is a triaxial accelerometer optimized for seismic applications. Inside the stainless steel housing are three orthogonally mounted low-noise EpiSensor force balance accelerometer modules.

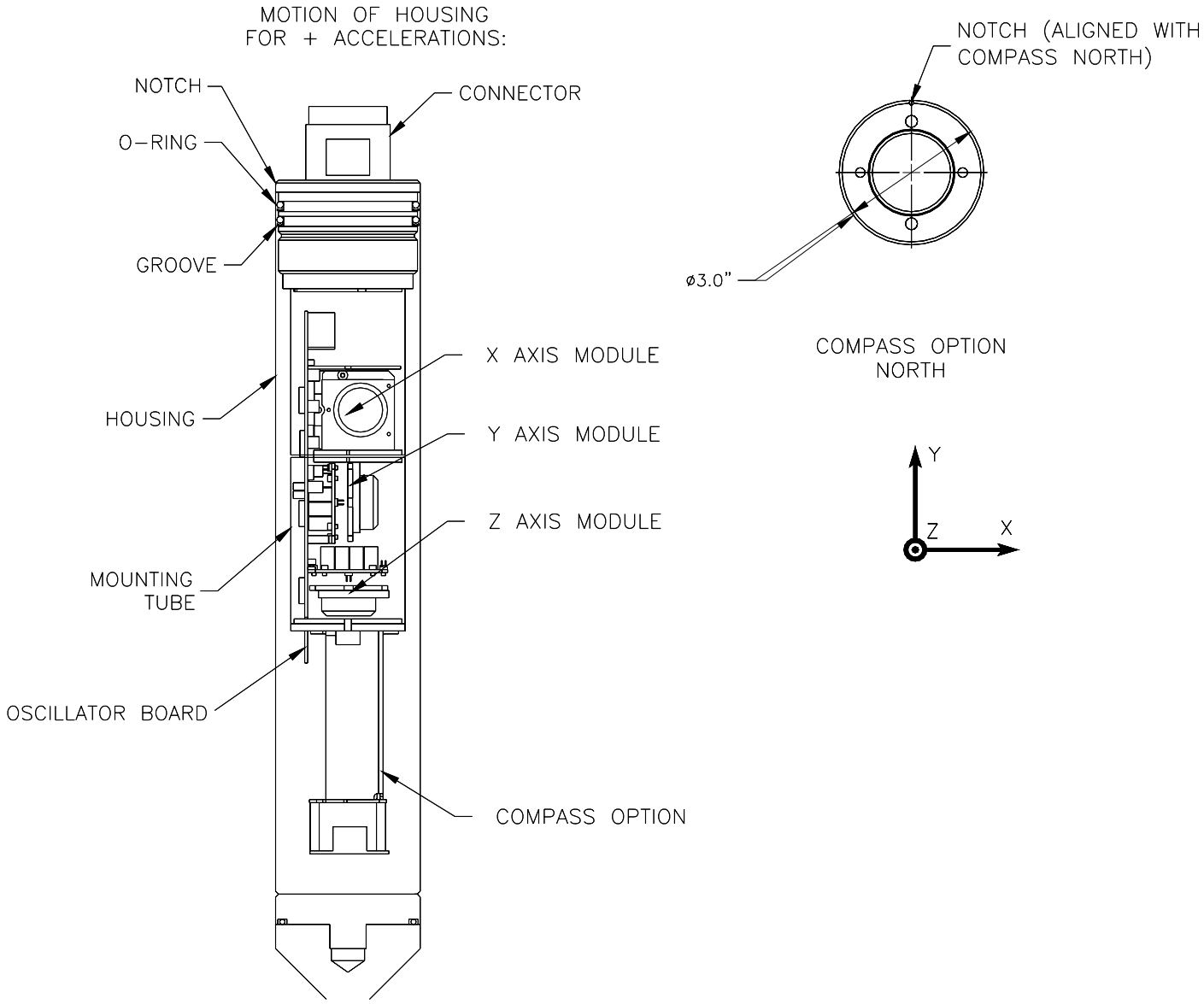
The housing, cables and connections are rated to 1,000 PSI (7 MPa), equivalent to a depth of 2,300 feet (701 meters).

The HypoSensor has user-selectable full scale recording ranges of ±4g, ±2g, ±1g, ±1/2g or ±1/4g. The HypoSensor bandwidth of DC to 200 Hz is a significant improvement over earlier generations of sensors. The output voltage levels are user-selectable at either ±2.5V or ±10V single-ended, or ±5V or ± 20V differential.

The HypoSensor is normally powered with a ±12V external DC power source. A single +12V power supply and compass are available as options.

Full specifications for the unit can be found in the Appendix.

Figure 1: The HypoSensor



Inspecting the HypoSensor

Carefully remove the HypoSensor from its shipping container. Although Kinemetrics takes every precaution in packing its systems, shipping damage can still occur. If you find a problem, note the condition of the shipping container. Then contact the freight forwarder and Kinemetrics as soon as possible.

Examine the HypoSensor. Its case should appear securely sealed, showing no sign of dents or other damage. Pay particular attention to the connector.

HypoSensor units should always be transported in the original shipping container to avoid damage.

The HypoSensor is shipped with an accessory kit that includes a zero-adjustment tool, spare o-rings, silicone grease, and a wrench for removing the sensor from the stainless steel housing.

2. Installation

This chapter contains information relevant to the installation of the HypoSensor unit. Our Services Group can provide additional expertise and borehole services.

This chapter covers the following information:

- Accessory Kit
- Inspecting the Connector
- Electrical Connection
- Functional check and zero offset measurement
- Accelerometer adjustment
- Using the compass option
- HypoSensor installation

Accessory Kit

The HypoSensor is shipped with the following accessories. These items are required for installation of the unit. Please contact Kinemetrics for replacement kits.

Kinemetrics P/N	Quan.	Item	Purpose
110393	1	Allen wrench	Tool for adjusting the zero offset
700281-026	3	O-ring	Seals the downhole cable connection
700281-231	2	O-ring	Seals the sensor to the main housing
870296	2	Seal ring	Improves o-ring seal
870299	1	Spanner wrench	Tool for opening unit

Inspecting the Connector

Before lowering the instrument into its hole, inspect the electrical connectors as follows:

- Unscrew the cable-end mating connector from the accelerometer package.
- Inspect the connectors to see that there is no dirt or contamination on any of the O-ring sealing surfaces and that both threads are perfectly

clean. Apply a small amount of the silicon grease supplied with your instrument to the O-ring in the cable-end mating connector.

- We recommend that the connector O-ring on the mating area be replaced at each servicing.

Electrical Connection

Align the mating connector keyway with the key in the bulkhead connector. Screw down the cable-end mating connector firmly.

Stand the package up so that it is vertical within ±1-1/2°. Use temporary braces or blocking to keep the package in this upright position while checking its operation.

A two-foot length of 4" PVC casing mounted with non-magnetic screws to a wood base works well as a support. Connect power as indicated in the *Operating Basics* section.

> ***Caution:*** When applying torque to the cable-end connector, two wrench flats must hold the bulkhead connector. Do not hold the HypoSensor package while applying torque because this may loosen the bulkhead connector from the package. This caution also applies when removing the connector.

Functional Check & Zero Offset Measurement

Measure and record the output voltage from each accelerometer with a digital voltmeter.

- Compute the offset of each axis in units of g (1g = 9.8 m/s^2).
- Divide the output voltage (V) by the sensitivity of the HypoSensor (V/g) quoted on the data sheets sent with the unit.

For example, if you have a unit with a sensitivity of 20 V/g and an offset voltage of 1 V, the offset would be 0.050 g -- often stated as 50 mg.

The higher of 50-mg offset or a 50mV voltage offset serves as a reasonable threshold for opening the package and re-zeroing the sensors, but this may vary from application to application.

Connect the HypoSensor to a data logger and perform the functional tests described in Chapter 2. If junction boxes (P/N 108375 and 105058) are used with the system, we recommend that they be connected to the circuit now to be sure that the whole circuit is operational. They also allow other voltages to be easily measured.

Perform a simple tilt test to check that all three axes are functioning properly and that the channels are wired correctly.

The horizontal sensors will undergo ±1g acceleration when tilted through 360°. The vertical sensor should measure 1g when the package is tilted on its side and 2g when the nose cone is pointing straight up.

If all three accelerometers have acceptable offsets for your application, and the tilt and functional response tests agree with the original calibration records, proceed with the installation.

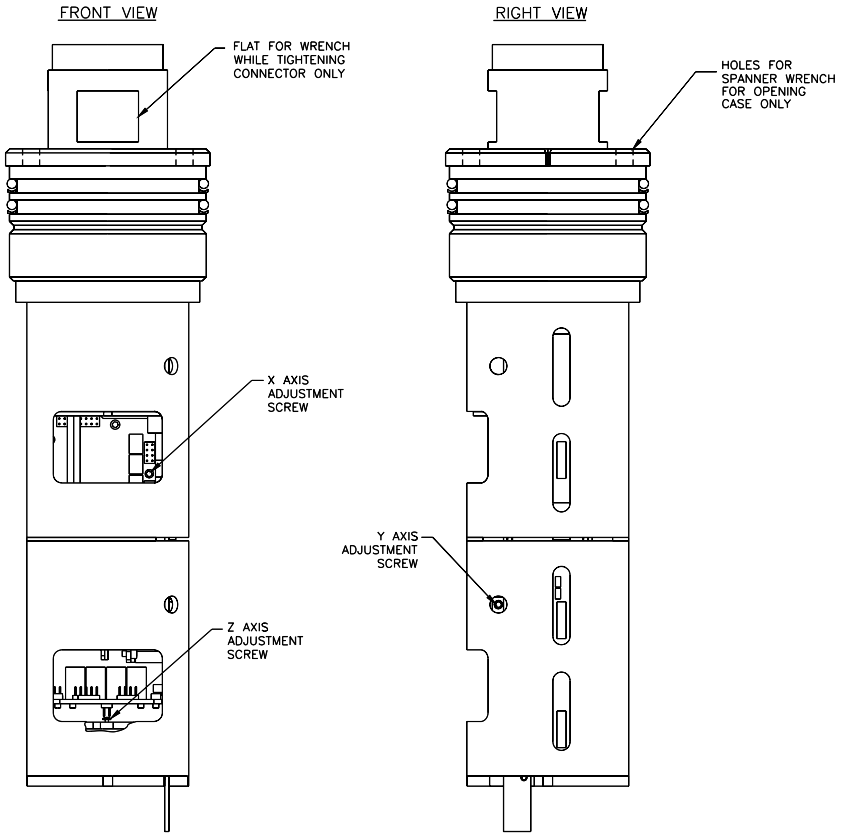
If the offsets and functional responses do not fall within acceptable ranges, zero the accelerometers as described in the next section.

Accelerometer Adjustments

This section describes a step-by-step procedure to adjust the HypoSensor in the field.

Remove the cylindrical housing from the package using the spanner wrench supplied in the accessory kit and a strap wrench.

Figure 2: Accelerometer adjustment screws


FRONT VIEW
FLAT FOR WRENCH WHILE TIGHTENING CONNECTOR ONLY
X AXIS ADJUSTMENT SCREW
Z AXIS ADJUSTMENT SCREW
RIGHT VIEW
HOLES FOR SPANNER WRENCH FOR OPENING CASE ONLY
Y AXIS ADJUSTMENT SCREW

Caution: Under no circumstances use the flats on the connector to unscrew or tighten the package into the housing. This could loosen the connector and damage the package wiring.

Caution: Potential electrostatic discharge (ESD) hazard to equipment. Wear a grounded wrist strap with impedance of approximately 1 M Ω when handling the HypoSensor circuit boards to protect components from damage.

Connect the required power to the cable (or connect the cable to a recorder).

Stand the accelerometer framework against a vertical surface. Be very careful that it does not fall over. The assembly should be level within 0.5°.

Measure the "zero" output voltage with a digital voltmeter.

Adjust the modules using the adjustment holes shown in Figure 2. Adjusting the vertical sensor is more difficult than measuring the horizontal sensors because the hex wrench is partially obstructed by one of threaded rod supports. Turning the adjustment screw clockwise will result in a more positive output. After you have adjusted the screw, tap the case with the hex wrench or a screwdriver handle to ensure the adjustment screw is “set” in position.

To convert the value to units of g, divide the measured value by the sensitivity. With some care, the channels can be adjusted to an offset of less than 5 milli-g. This corresponds to a tilt in the horizontal channels of 0.29° – more than sufficient for a borehole installation. If you decide to leave a higher offset than 5 milli g it will not affect your data quality. The only thing a high offset does is reduce the highest signal that you can record, but for any reasonable offset this is a very small change. For example with a 1 g full scale range and 100mg offset the largest signal you can record will now be 0.9g versus 1g for a perfectly balanced accelerometer.

Replace the cylindrical housing, being careful not to damage the O-rings or backing rings near the top of the connector-end of the stack.

Be very careful not to gall or cross the threads when screwing the package together. If the package appears to jam before it is fully engaged in the tube, *do not* attempt to force the package in further.

If you encounter resistance, unscrew the package, remove any debris on the threads and be sure there is a thin coat of grease (880718) on them. Use a strap wrench and the spanner wrench provided with the unit.

Caution: Never use the flats on the connector to unscrew or tighten the package into the housing. This could cause the connector to loosen and damage the wiring.

Using the Compass

Before the package is lowered into the hole, the functionality of the compass device must be confirmed and calibrated for the local magnetic environment.

You will need to know the direction of magnetic north at the field site. A rough estimate can be made using a normal magnetic compass.

The precise declination (difference of Magnetic North from true or grid north) can be determined from a current topographic map of the area.

Make the appropriate adjustment for the current date or use the data derived from a model of the magnetic pole. Magnetic field software is available from a United States Geological Survey web site: http://geomag.usgs.gov/models.html. Additional information is also available at http://www.ngdc.noaa.gov/seg/potfld/geomag.shtml.

It is also important to know the magnetic dip (angle that the earth's magnetic vector makes with the horizontal) at the site. The compass will function correctly if the magnetic dip is within the range of – 80 to +80^{o}.

We strongly recommend installing and using the Kinemetrics-supplied software on the PC used to communicate with the compass. Instructions on the use of Kinemetrics' *Compass* program are described in *Chapter 4*.

The following section explains how to connect the compass to the power supply and the RS232 connector on the PC.

Compass Connection

The power supply for the compass (white wire, compass +12V, Pin 13) is separate from the power to the accelerometers. We suggest only applying power to the compass when it is actually being used in the initial installation of the package and for subsequent testing of its functionality and package location.

If you are using an Altus-series recorder, the compass can be *temporarily* powered from the +12V line between the recorder and HypoSensor.

See the *Auxiliary* section in Chapter 5 of the *K2 User Guide* for more information on temporary, auxiliary power sources and Chapter 4 in the *Etna Operations Manual.*

If you are using non-Kinemetrics equipment, we recommend using a separate, user-supplied DC power source capable of providing 12 $\pm$ 1V at 40mA.

It is important to switch the power to the compass on *quickly*, to be sure that the on-board microprocessor's power-on reset function works correctly.

The compass provides a DC output of 0.1 to 1.9V (on the orange wire, compass output, Pin 12). This output voltage should be referenced to RS 232 ground/compass end (blue wire. Pin 9). Measure the voltage with a DVM with at least 20 kΩ input impedance.

The analog output is not as accurate as the compass' digital output, adding another ±1° of azimuth uncertainty. We recommend that this output be used mainly as a functional check for the compass or when a PC is not available.

The compass communicates through a bi-directional RS232 link. A connecting cable is required from the HypoSensor cable, or preferably, the wellhead box terminal to the PC. The cable should connect as indicated in this table:

Function	HypoSensor Connector	HypoSensor Cable Assembly	PC Connection DB-9	PC Connection DB-25
RS 232 GND	Pin 9	Blue	Pin 5	Pin 7
RS 232 TXD	Pin 10	Twisted Pair Black	Pin 2	Pin 3
RS 232 RXD	Pin 11	Twisted Pair White	Pin 3	Pin 2

Starting the Compass

Start the *Compass* program by inserting the supplied CD into the PC, run the Setup to install the program. Follow the installation instructions and then start the program from the Compass icon.

Select **Configure System** and configure the software for the correct COM port and a baud rate of 4800.

At this point the parameters loaded into the compass and stored in the EEPROM should allow it to correctly function with the PC. We suggest that you do not alter any of the compass parameters until the initial checkout has been completed.

Check the functionality of the compass by selecting **Terminal Mode**. The compass should continually send a message in the following format:

```
$271.8,D,OK*FF
```

where 271.8 will be replaced by the actual heading of the compass and FF will be replaced by the actual checksum of the message.

If you see a message that is different in format from the one displayed above, type the following commands:

h<ENTER>

=t1<ENTER>

s<ENTER>

Rotate the package and check that the heading part of the message changes. This confirms that the compass is working properly. If no message appears, turn off the power and check all the electrical connections to the compass.

Check that the RS 232 port is correctly connected and that the correct communications port has been selected. Re-apply the 12V power to the compass by switching it on rapidly to be sure that the compass microprocessor correctly performs its power on reset, and check the message.

If the message still does not appear, measure the voltage on the compass analog signal line (orange wire, Pin 12). The voltage should be between 0.1 and 1.9V and vary as the package is rotated.

If the voltage does vary, then the problem lies in the RS232 connection to the compass. Check the RS232 connections and the computer COM port connections thoroughly.

Auto-Calibrate Compass

Auto-calibrate the compass by selecting **Auto Calibration** from the menu and rotating the compass through angles of approximately 0, 45, 90, 135, 180, 225, 270 and 315^{o}.

The initial heading does not have to be zero, although this may simplify the procedure; nor does the rotation increment have to be exactly 45^{o}. The auto-calibration merely requires 8 approximately equally spaced points to determine the local magnetic field conditions and to correct for the instrument's soft and hard magnetic errors.

The compass must be located well away from sources of magnetic interference, such as soft iron or steel, permanent magnets, or varying magnetic fields created by current-carrying conductors.

If the magnetic environment is very poor or the calibration procedure has not been performed correctly, the compass will indicate a bad calibration and not up-date its coefficients.

A calibration score of 8 or 9 indicates that a good calibration has been obtained. A score of 7 is marginal, while scores below 7 indicate that the calibration should be repeated.

The compass should now be orientated toward Magnetic North. Confirm the direction it indicates with either a magnetic compass or, preferably, with reference to a topographic map aligned to known landmarks.

A significant difference between the Magnetic North indicated by the compass and the map indicates a possible problem in the compass or that the site has a large magnetic anomaly.

You may now use the compass variations and offset "A" functions to correct the compass so that a heading of 0° corresponds to True North and/or is orientated with the Y (+) axis of the accelerometers.

TRUE NORTH (+) CORRECTION

By inserting the angle measured *clockwise* from True North to Magnetic North into the variation register, the compass heading will be relative to True North.

HypoSensor Installation

When both the accelerometers and the compass are working correctly, the package can be lowered into the hole.

If you are using Kinemetrics equipment such as loading poles or a hole lock to install the package, follow the instructions included with those options.

The following instructions make a number of assumptions:

- That the package is lowered into the hole with either the Kinemetrics-supplied cable with a Kevlar stress core, or
- The package weight is supported by a stainless steel wire tension member
- That the compass option was used to determine the final resting orientation of the package when it is locked into place
- That the hole has been cased with PVC and filled with water to support the casing

Other recommended procedures:

- Case the holes with 20-foot sections of 4-inch schedule 40 (4.500-inch OD × 4.026-inch ID) PVC pipe glued together with couplings between segments
- Glue a cap to the bottom segment
- Grout the casing into the hole with a bentonite mixture that will have the same strength as soil
- A grout mixture that has proved satisfactory in the past is specified in ASTM D-4428/4428M. The proportions are :

  1 pound bentonite
  1 pound Portland cement
  3 quarts water

- Restrain the package while carefully lowering it through the hole casing to the bottom of the hole with a winch or a pulley arrangement. The unit can be powered or unpowered during the decent.

One person can successfully lower the package into holes up to 1,000 feet if the casing has been filled with water due to the offsetting weight of the buoyancy of the cable and package.

The apparent weight of the package and 1000 feet of cable is only approximately 85 pounds. If you are not using a hole lock, this process is easier if the package is fitted with the optional centering spiders that keep it centered in a 4-inch inside-diameter cased hole.

Check the orientation information when the package is at the bottom of the hole with the compass and the balance of the accelerometers. The accelerometers should be balanced to within the acceptable tolerance. This tolerance will vary with each application.

If this is not the case, it indicates that the hole orientation is not vertical. The accelerometers must be compensated for this offset. Record the offset at the bottom of the hole, remove the package, and "zero" the accelerometers to the negative of the downhole offset.

Note: This procedure will only work if the package can be returned to the same angular orientation down the hole.

The compass option will not work if the orientation of the hole is more than 16^{o} from vertical. This angle can be calculated from the outputs of the horizontal sensors.

Although we recommend using loading poles to get a specific orientation, it is not absolutely necessary. It is possible, with patience, to rotate the package to the desired orientation by actually lifting it and twisting the HypoSensor cable while observing the output of the compass.

This technique has been used on a 700-foot installation, centering the package with the spider option.

When the accelerometers are correctly balanced and the package orientation is satisfactory, lock it in place with a suitable material, such as small glass or smooth rock spheres (<1/4-inch diameter). This material will allow you to retrieve or move the HypoSensor package at a future date.

If you wish to cement the package into place permanently, we strongly recommend that you first test the installation for at least two or three weeks.

If you do choose to cement the package permanently, use enough material to fill the cavity between the package and the casing completely and to leave some material on top of the package.

Because of its rough surface, ordinary gravel may not "flow" into the area between the package and the casing, while sand may liquefy in a strong motion event.

The Kinemetrics hole lock mechanism is recommended if frequent retrievals are anticipated.

Make careful notes of the offset settings and variations displayed on your PC to be sure that the orientation is correct.

3. Operating Basics

The HypoSensor is designed as a very flexible, low-noise accelerometer and can be configured to satisfy a wide variety of acceleration-sensing requirements.

This chapter is organized as follows:

- Power requirements
- Electrical connections
- Polarity conventions
- Description of configurations
- Functional test with an Altus recorder
- Using the calibration coil
- Optional compass

Power Requirements

The HypoSensor is supplied in two power configurations. The basic unit requires +/-12 V for operation. An optional internal DC/DC converter allows operation with only +12 V.

The data sheet sent with the unit indicates whether it is a dual or single supply version. If it is a single supply unit, it is also shipped with a label on the connector-end of the sonde.

> **Note:** This label may fall off after repeated installation of the unit. *If you have any doubt about the power configuration, call Kinemetrics.*

It is essential that the unit be supplied with adequate power. *Be sure to take into account any power loss that might occur due to the cabling.* The HypoSensor is designed for use with Kinemetrics' downhole cable 700306.

Since downhole units often use long cables between the sensor and the recorder, the resistive loss in the cable can be significant. See the reference section for a complete explanation.

Electrical Connection

The connections for the HypoSensor are described below, along with procedures for using the calibration and cal enable signals, and the optional compass. This information should be sufficient to allow the HypoSensor to connect to the user's own equipment or any Kinemetrics recorder.

Cable and Connector Wiring

The connector-pin outs and the wiring colors of the HypoSensor cable assembly are provided below.

To aid in connecting this system to a transient protection box (P/N 108390), the corresponding connections on J3 and J4 in the box are also shown in the table, along with connections to an Altus external input board.

Table 1: HypoSensor assembly wiring chart

K2 External FBA Option	Transient Protection Box		HypoSensor Cable 700306		
J1	**J1, J3**	**J4**	**Cable Assembly Wiring Chart**		
			Cable wire colors on 700306	Function	Connection pin # on HypoSensor
L	1		TP1 red	X+ signal	1
M	2		TP1 white	X– signal	2
N	3		TP1 shield	X shield	
A	4		TP2 green	Y+ signal	3
B	5		TP2 white	Y– signal	4
P	6		TP2 shield	Y shield	
C	7		TP3 yellow	Z+ signal	5
D	8		TP3 white	Z– signal	6
R	9		TP3 shield	Z shield	
K	13		Black	Common	7
U	15		Cable shield	Shield	8
		5	Blue	RS-232 GND	9
		4	TP4 black	RS-232 TXD	10
		6	TP4 white	RS-232 RXD	11
		7	TP4 shield	RS-232 shield	
		3	Orange	Compass signal	12
		2	White	Compass +12V	13
			Not connected		14
E	10		Green	CALDAC	15
F	11		Yellow	CCE	16
J	12		Red	+12V	17
H	14		Brown	-12V *	18
			Not connected		19

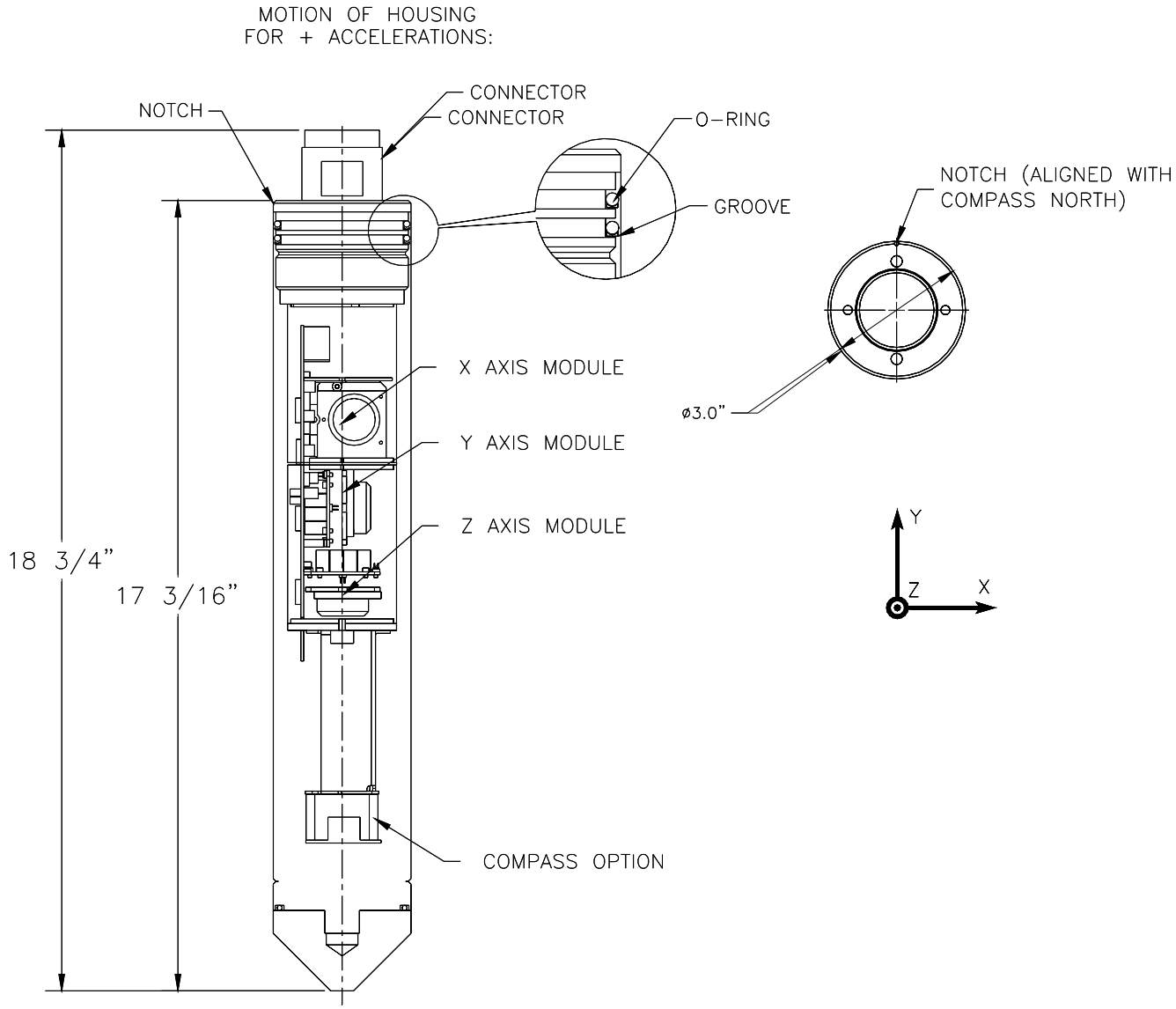
*** Note:** Connect only at sensor end for single supply option. N/C at recorder end. OK to connect sensor to well head box.

Polarity Conventions

Unlike previous generations of Kinemetrics force balance accelerometers, the HypoSensor uses a right-handed, X Y, Z coordinate system with a positive output for acceleration along each axis.

Previous Kinemetrics FBA designs used an alternate coordinate system (L, V, T) and produced a negative output for positive acceleration along each axis. With modern feedback sensors, this convention dating from the days of passive seismic sensors is losing acceptance. Today's user requires an accelerometer that produces useful data without regard to the internal workings of the sensor. The extended bandwidth, flat frequency response and polarity of the HypoSensor meet these demands.

Figure 3: HypoSensor polarity conventions



Configurations

The HypoSensor can be configured to obtain a variety of output types and sensitivities. The variety of configurations is described in more detail in the *Reference* section of this manual.

The data sheet provided with your unit indicates the sensitivity of the sensor. This can be checked with the results of the functional test described in the next section.

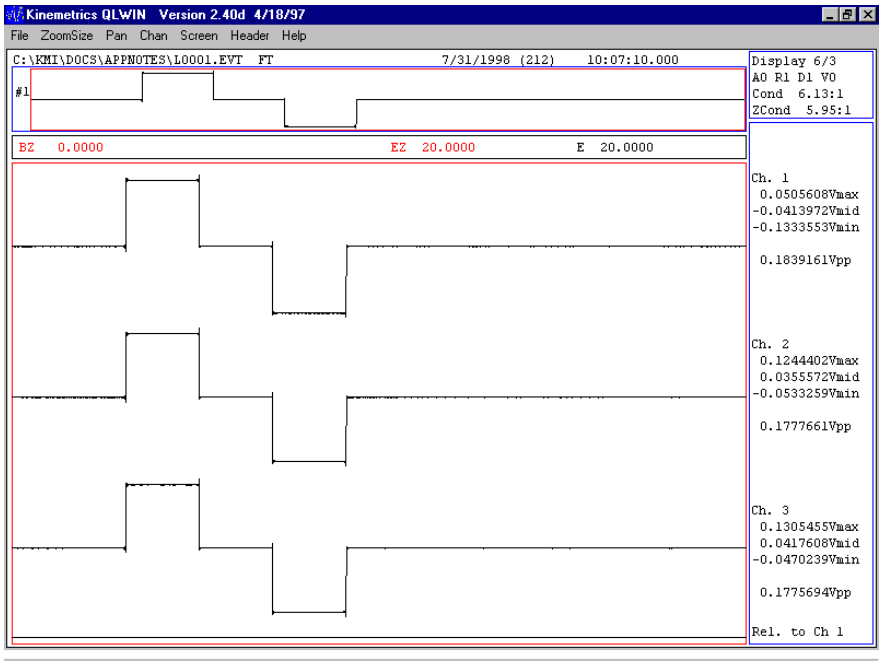
We recommend that you do not alter the factory settings of the HypoSensor.

Performing a Functional Test with an Altus Recorder

Please refer your recorder's user manual for instructions on performing functional tests.

Altus instrument firmware released after August 1, 1998 performs a dual polarity pulse test on HypoSensors as the standard functional test when correctly configured. This firmware is available at the Kinemetrics website.

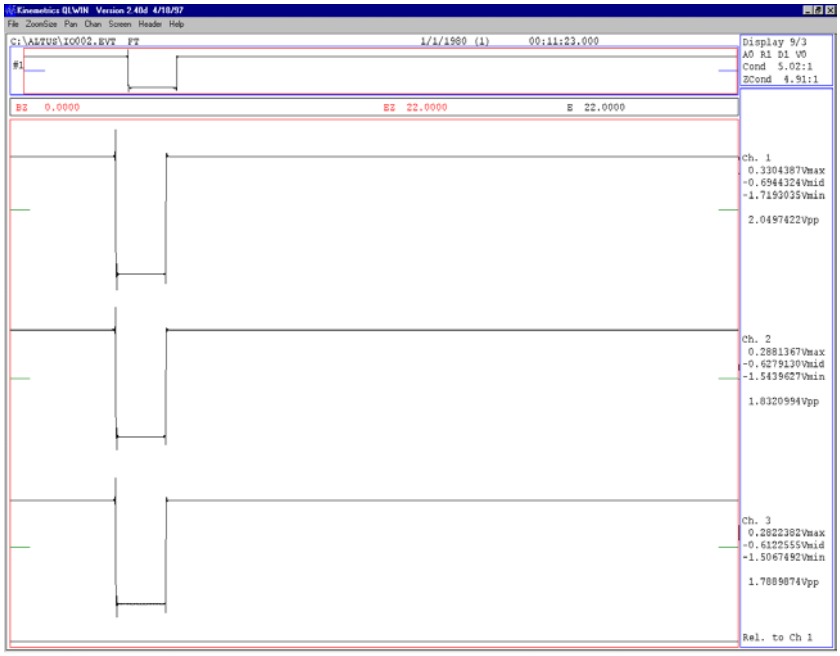
Figure 2: Display of functional test



The height of the pulse will depend on the full-scale setting of the instrument but will correspond to a g level of approximately 0.125g. The exact value will be 2.5V multiplied by the sensor module's calibration coil sensitivity value provided on the sensor's data sheet.

Altus software released prior to August 1998 supports functional tests on the earlier generation of Kinemetrics force balance accelerometers but does not support the HypoSensor. If you perform a functional test or sensor response test on a HypoSensor using older software, the record will appear as in the screen in Figure 3.

Figure 3: Display of functional test using software released prior to August 1998



The record looks like this because the calibration coil enable is only enabled during the undamped portion of the old FBA-11 style functional test.

Sensor Response Test

The sensor response test for the HypoSensor, using Altus software released after August 1, 1998, measures the response of the sensor to white noise input. The digital-to-analog converter in the recorder drives the calibration coil with an analog voltage corresponding to a pseudo-random number sequence. The resulting file contains the information needed to compute the sensor response. For more information on the sensor response test consult the Kinemetrics website.

Using the HypoSensor Calibration Coil

This section contains the information necessary to use the calibration coil with equipment other than Altus recorders, such as a spectrum analyzer or a different type of data logger.

Each HypoSensor module is equipped with a calibration coil. This coil is isolated from other circuitry and accurately simulates the effect of an acceleration on the system. This coil can be used to verify both the static acceleration sensitivity of the HypoSensor and the dynamic response of the system. The Altus recorder functional and system tests use a calibration signal from the recorder's digital-to-analog converter (DAC).

To produce a functional test sequence, the recorder must control the CAL and CCE line to the HypoSensor.

Even if the recorder cannot produce a functional test, it is still very important that these lines be held at the correct potential.

The CAL line is not connected to the sensor unless the CCE line is active, but to provide the best noise performance the CAL line should not be left floating. We suggest that the CCE line be grounded to power common when the calibration coil is not in use.

The CCE line drives a transistor that operates an analog switch that connects the CAL line to the sensor module calibration coil. The transistor will turn on the analog switches at voltages between +5 to +12V. The transistor is not activated at voltages below 0.5V. This means a CMOS driver can drive the line or an open collector output pulled up to 12V.

A transistor-transistor logic (TTL) level will probably work if the sensor is close to the digitizer.

It is very important that the CCE line is not enabled when the calibration feature is not in use and that it is not powered when the unit is not powered. This is because the CAL line is connected to all the sensor coils during the calibration sequence, which can result in both additional noise and cross coupling between the sensors. The easiest way to prevent power conflicts from the CCE line is to connect it to the power common or the –12V supply of the HypoSensor.

To produce a functional test sequence, the data logger needs to control both the CAL and the CCE lines. The voltage applied to the CAL line should be limited to +/-10V. The sensor should reproduce any signal applied by the digitizer within the voltage limits and the bandwidth of the sensor. Thus, the calibration sequence can range from the simple pulses described below to single frequency sine waves or chirped sine signals.

> ***Caution:*** Be certain that the CAL line is not active when the HypoSensor is not powered – this could damage the unit.

If the data logger cannot perform a functional test, a simple test box can be built to simulate the desired calibration sequence.

A suggested sequence is as follows:

1. Apply 0V to the CAL line
2. Apply +12V to CCE
3. Wait 2 seconds
4. Apply +2.5V to CAL for 2 seconds
5. Change CAL to -2.5V for 2 seconds
6. Change CAL to 0V for 2 seconds
7. Turn CCE off by connecting it to 0V

This will produce a positive pulse followed by a negative pulse.

Caution: The CCE line must not be enabled during normal operation – severely degraded noise performance can result. Applying voltage to the CAL line when the unit is not powered will result in damage. Applying voltage above the power supply lines to the CAL line will also damage the unit.

If you wish to use a current source to calibrate the unit, the nominal sensitivity is 0.11 g/mA and the resistance of the calibration coil and sensitivity setting resistor is approximately 1700Ω. Never apply currents in excess of 40 mA. Apply currents in excess of 5 mA (and below 40 mA) only for intervals shorter than 20 seconds.

4. Software Operation

The Compass Software (P/N 301645) is designed to allow the user to easily configure and communicate, via the RS232 link, with the compass option in the downhole package. The software allows the user to:

- Set up the communications parameters in the host PC
- Set-up the internal parameters within the compass
- Perform a field calibration of the compass
- View the compass heading in an easy-to-read graphic format

A terminal emulation feature is also provided to allow access to more advanced compass options.

Hardware Requirements

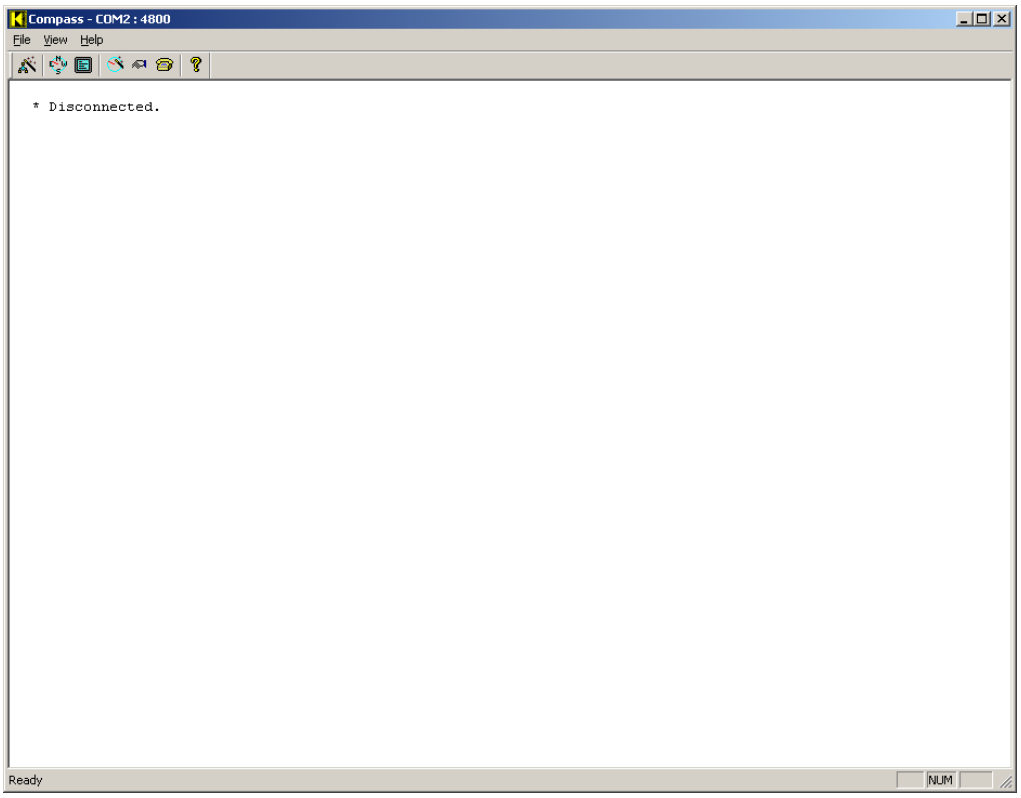
The *Compass* software requires:

- An IBM PC-compatible computer
- 16MB of RAM
- A CD-ROM drive
- An unused COM1-COM16 communication port
- An operating system of Windows 95, Windows 98, Windows ME, Windows NT, Windows 2000, or Windows XP

The specifics of the cabling required for connection to the HypoSensor package are detailed below.

Operation

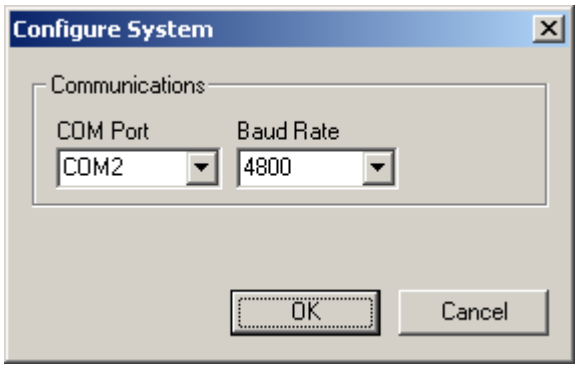
Click the Compass icon to start the program. Your computer screen will display a screen that looks something like this:



To begin, select **Configure System**.

Configure System

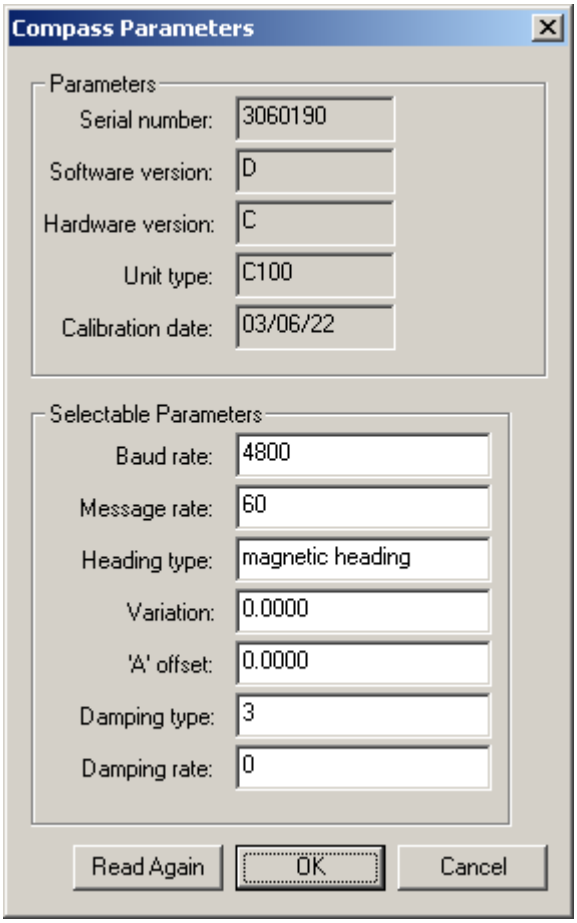
You will now see a dialog that looks something like this:



This dialog allows the user to configure the PC to correctly communicate with the compass option. Select the correct COM port for communication with the compass and the baud rate the compass is working at. The factory default is 4800 baud. Return to the main menu by pressing **OK**.

Compass Parameters

This dialog shows the compass' serial number, software version, etc, and allows the user to reconfigure the most important of the compass options. It will look something like this:



When the menu is exited by pressing **OK**, the compass parameters will be updated in the compass's EEPROM. To quit the menu without updating the compass, press **Cancel.**

The Baud Rate selection allows the user to choose the baud rate at which the compass communicates. New baud rate selections are effective immediately after pressing **OK**.

Before changing the baud rate in an installed HypoSensor package, check that the new rate works correctly given the cable length used in the installation. Failure to check this could result in the package having to be retrieved to reset the compass!

The Message Rate allows selection of the rate of output of the compass messages.

Heading Type selects from the different messages that the compass can output. Selecting anything other than Message Type 1, KVH Heading, will result in the failure of the graphic display.

This option should only be changed if you have specific requirements for the Other Message formats.

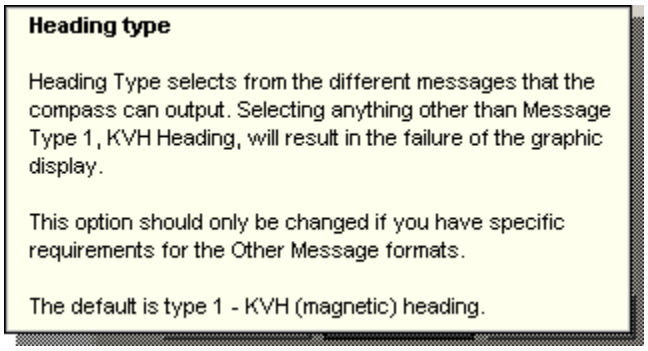
The Variation option allows the user to enter the magnetic declination of the site so that the compass heading will be a true bearing. Be certain to set the correct value for this parameter.

The 'A' offset allows a correction to the compass heading option. See the *Compass Program Command Line Communication* section for further information.

Damping Type allows the user to select the compass' filter response type. You may wish to experiment to see which gives the most useful values during installation of the package.

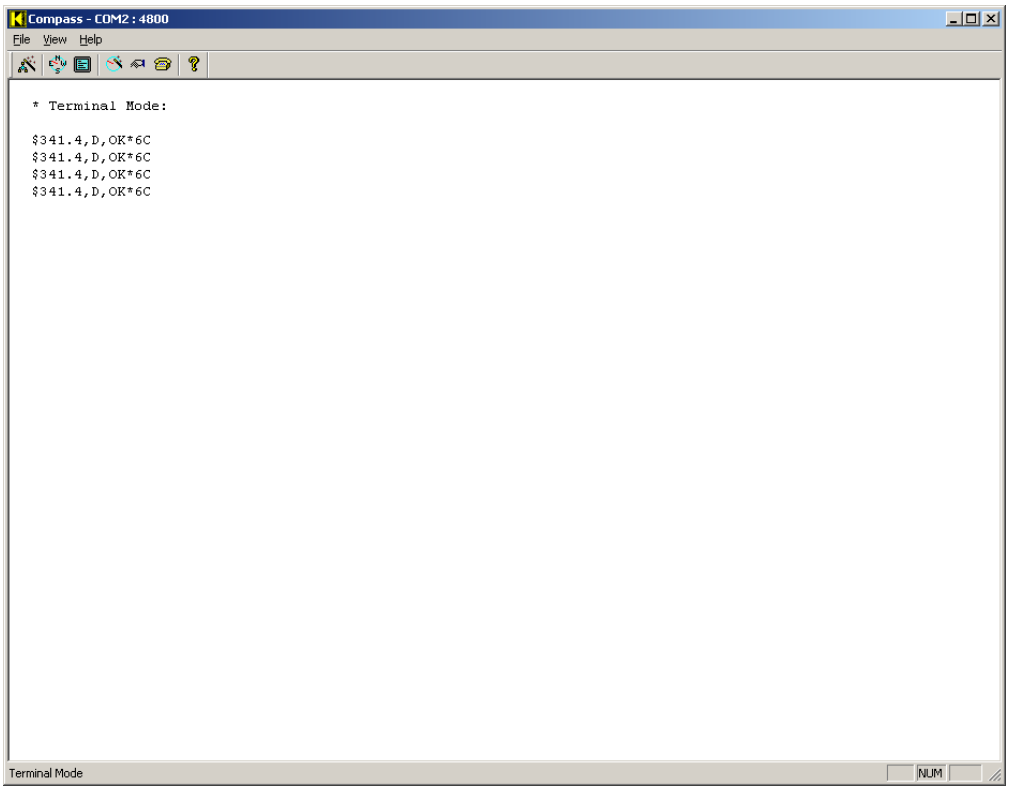
Damping Rate gives the time constant for the damping of the compass filters. Again, experiment to determine the optimum setting for each installation.

NOTE: You can get on-line help from the program by clicking on one of the parameter fields and then pressing F1. You will get a pop-up help screen that looks like this:


Heading type
Heading Type selects from the different messages that the compass can output. Selecting anything other than Message Type 1, KVH Heading, will result in the failure of the graphic display.
This option should only be changed if you have specific requirements for the Other Message formats.
The default is type 1 - KVH (magnetic) heading.

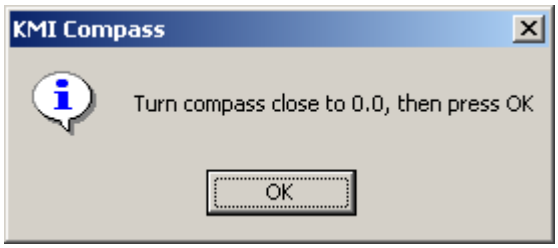
Terminal Mode

Terminal Mode allows the user to communicate with the compass as if the PC was a dumb terminal, providing access to all compass commands detailed in this chapter. These commands should be used with care, as some can have adverse affects on the compass' performance. Exit Terminal Mode by selecting another communication mode or by pressing **Disconnect**.



Calibrate Compass

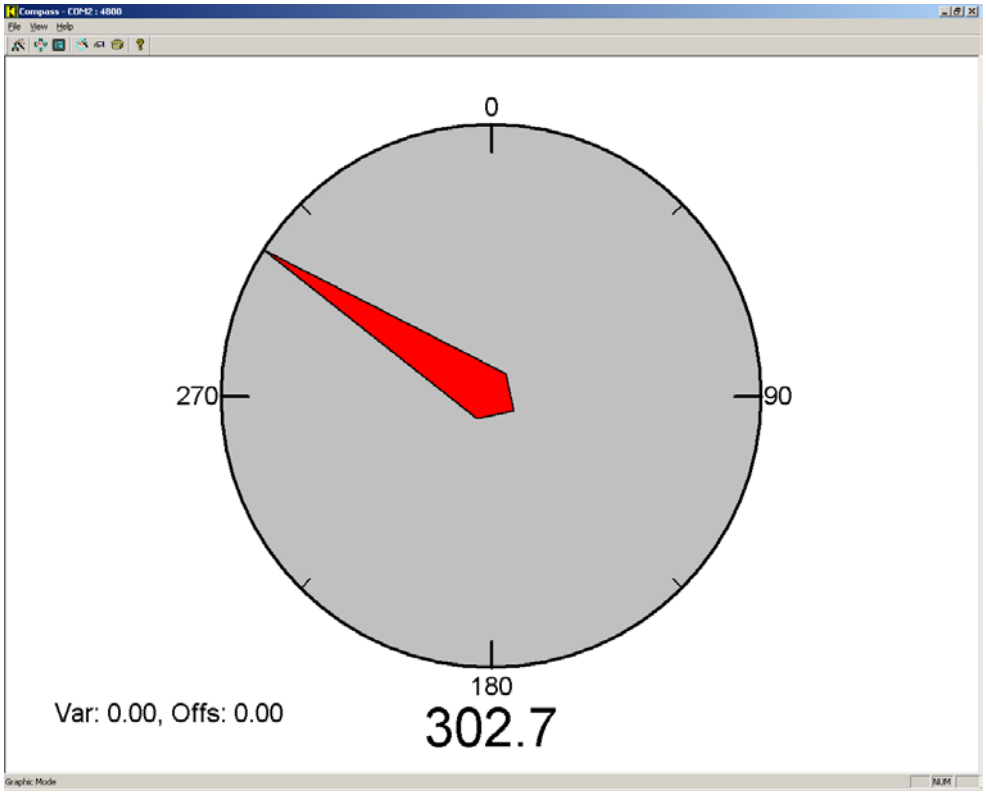
This option allows the user to perform a field calibration on the compass by rotating the HypoSensor package through increments of 45°. This allows the compass firmware to perform an auto-calibration to remove the effects of the hard and soft magnetic components in the HypoSensor package.



See *Using the Compass* in Chapter 2 for further details.

Graphic Mode

The graphic display option provides a compass rose with a visible indicator showing the current compass orientation and a digital readout of the compass heading. The screen also shows any variation or offset value that is currently being used by the compass. Exit the graphic display option by selecting another communication mode or by pressing **Disconnect**.



5. Maintenance

Recommended Maintenance

The HypoSensor is designed for many years of unattended use, but we recommend that you perform a functional test once a year. See the Altus recorder manual or Chapter 3 of this manual for more details. For an installed downhole unit, only the functional testing is necessary.

Complete a Functional Test

Kinemetrics recommends that you perform a functional test on the accelerometer at each service visit to check that the unit is operational and to keep as a baseline record for future visits. Refer to *Chapter 3* for instructions on performing the functional test. If the unit is connected to an Altus or other Kinemetrics recorder, refer to the recorder's manual for instructions on performing the functional test. Refer to *Chapter 6* if the unit is connected to a non-Kinemetrics data acquisition system.

Desiccant Replacement

The HypoSensor contains a small package of desiccant that is designed to maintain low humidity level inside the unit and prevent condensation. If the instrument is sealed, this should never need replacement. However, if the stainless steel housing is left unsealed in a humid environment for a prolonged period of time, the desiccant may be incapable of absorbing more moisture. This is indicated by the ink on the desiccant pack turning from its original blue to pink. When this happens it should be replaced.

New desiccant can be ordered from Kinemetrics. Be sure to follow electro-static discharge (ESD) precautions when opening the sensor case.

Caution: Potential electrostatic discharge (ESD) hazard to equipment. Wear a grounded wrist strap with impedance of approximately 1 M Ω when handling the EpiSensor circuit boards to protect components from damage.

Troubleshooting and Repair

If your HypoSensor does not appear to be working, we suggest you first check that the cabling and power supply are correct. If the problem persists we recommend you return the unit to Kinemetrics for repair and re-calibration.

Examining & Cleaning the O-rings

The O-rings should be cleaned each time the unit is opened and exposed to dirt. To clean the O-ring, remove it from the seal surface, wipe away the silicon grease and examine it carefully for any tears, abrasion, hairs etc. that could prevent a seal.

Before replacing the O-ring, clean the seal surface with a cotton swap and examine it carefully for scratches.

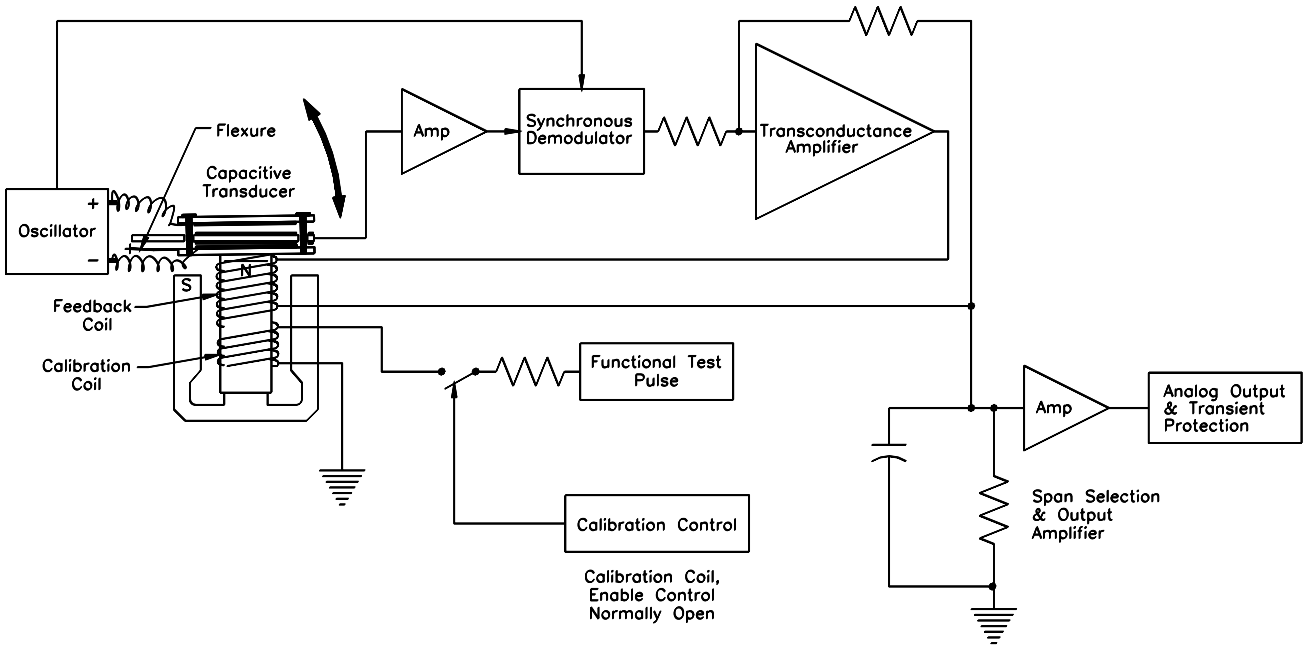
6. Reference

Theory of Operation

The HypoSensor consists of three orthogonally mounted force balance accelerometers (FBAs) – X-axis, Y-axis and Z-axis – inside a sensor casing. Each accelerometer module is identical and plugs into a board that provides the final output circuit and the carrier oscillator.

The figure below shows a simplified block diagram of the major components of each of the FBAs.

Figure 4: Simplified block diagram of an accelerometer



Working Principle

- The oscillator applies an AC signal of opposite polarity to the two moving capacitor plates (also referred to as "the moving mass"). When the accelerometer is "zeroed" and when no acceleration is applied, these plates are symmetrical to the fixed central plate and no voltage is generated.
- An acceleration causes the coil and capacitive sensor plates, which are a single assembly mounted on mechanical flexures (springs), to move with respect to the fixed central plate of the capacitive transducer.
- This displacement results in a signal on the center plate of the capacitor becoming unbalanced, resulting in an AC signal of the same frequency as the oscillator being passed to the amplifier.
- The amplifier amplifies this AC signal.
- This error signal is then passed to the demodulator where it is synchronously demodulated and filtered, creating a "DC" error term in the feedback amplifier.
- The feedback loop compensates for this error signal by passing current through the feedback coil to create a magnetic restoring force to "balance" the capacitor plates back to their original null position.
- The current traveling through the coil is thus directly proportional to the applied acceleration. By passing this current through a complex impedance consisting of a resistor and capacitor, it can be converted to a voltage output proportional to acceleration with a bandwidth of approximately 200 Hz.
- Selecting a particular resistor value sets the full-scale range. The resistor values are determined by a high accuracy network, so the range can be set at 0.25g, 0.5g, 1g, 2g, and 4g without re-calibrating the sensor span.
- The capacitor and overall loop gain are selected along with the resistor to ensure an identical transfer function on each range. *This is why two sets of jumpers must be changed together to modify the range.*
- The voltage output of the resistor capacitor network is set at 2.5V for the acceleration value corresponding to the particular range. For example, with the 2g range, a 1g acceleration would cause a 1.25V output, on the 4g range, 1g would result in a 0.625V output.

This voltage is then passed into the amplifier:

- The low-power amplifier amplifies this signal by either 1 or 4 (selected by jumpers) to give a single-ended output of either ±2.5V or ±10V. A precision resistor network also determines this gain value.
- The low-noise amplifier (selected by jumpers) provides a lower noise output at the cost of additional power. This amplifier again amplifies the signal by 1 or 4 to give a single-ended output of either ±2.5V or ±10V.
- A second amplifier is also present which inverts the signal from the first and can be connected to the negative output lead (via jumpers).

This allows the unit to give a differential ±5V or ±20V to match the input to 24-bit digitizers.

Features

Each HypoSensor module is equipped with a calibration coil. Applying a current to this coil simulates the effect of an acceleration applied to the sensor.

- The calibration coils are open circuit in normal use to prevent cross talk and noise pick-up. To utilize the calibration coil remotely from outside the unit, the calibration coil enable signal must be activated by applying a DC voltage of +5V to +12V with respect to ground.
- A voltage signal applied to the calibration line with CCE is active will cause all three HypoSensor modules to respond with an acceleration output of approximately 0.05 g per volt applied. The exact calibration coil sensitivity is provided on the data sheet of each module.
- This voltage mode will normally be used for checking the response of the sensor remotely from a digitizer. If you wish to use a current source to drive the calibration coils in a laboratory setting, they may be accessed by removing the HypoSensor's case.
- All external connections are passed through double-stage transient protection. This protection consists of a gas arrestor between the line and protective ground. This is followed by a series impedance and solid-state low-voltage transient protection device connected between the line and protective ground.
- These elements protect the sensor from the effects of lightening induced transients and electro-static discharge (ESD). Each line is also filtered to prevent the entry of electro-magnetic interference or radio frequency interference (EMI/RFI) to the sensor.
- Optionally, the unit can be equipped with a +12V to ±12V converter module allowing the HypoSensor to be powered from a single 12-15V supply.

Pole Zero Representation of the HypoSensor

HypoSensor accelerometers are closed-loop, force-feedback sensors measuring the relative displacement of a moving mass (plates) with respect to the sensor case. The sensor's transfer function (TF) depends almost entirely on the electronic components rather than on the mechanical components of the sensors. The influence on the transfer function of the mechanical damping, spring elements and internal RC low-pass filter in the trans-conductance amplifier stage within the closed-loop path of the sensor are negligible for most applications.

We have determined a good empirical model of the system, which uses two pairs of conjugate poles to represent the transfer function of the instrument. If this transfer function is corrected for the DC sensitivity of the sensor, the amplitude agreement is within ±.0.5 dB over the bandwidth of the sensor. The phase agreement is within ± 2.5° in the 0-100 Hz band and within ± 5° over the full bandwidth of the instrument. This model can be represented as:

$$\frac{V(s)}{A(s)} = \frac{k1 * k2}{(s-p_1)(s-p_2)(s-p_3)(s-p_4)}$$

where $k1 = 2.46 \times 10^{13}$

k2 = Sensitivity of sensor in V/g (from Table 3-1)

s is the Laplace transform variable

$p_1 = -981 + 1009i$ (Pole 1)

$p_2 = -981 - 1009i$ (Pole 2)

$p_3 = -3290 + 1263i$ (Pole 3)

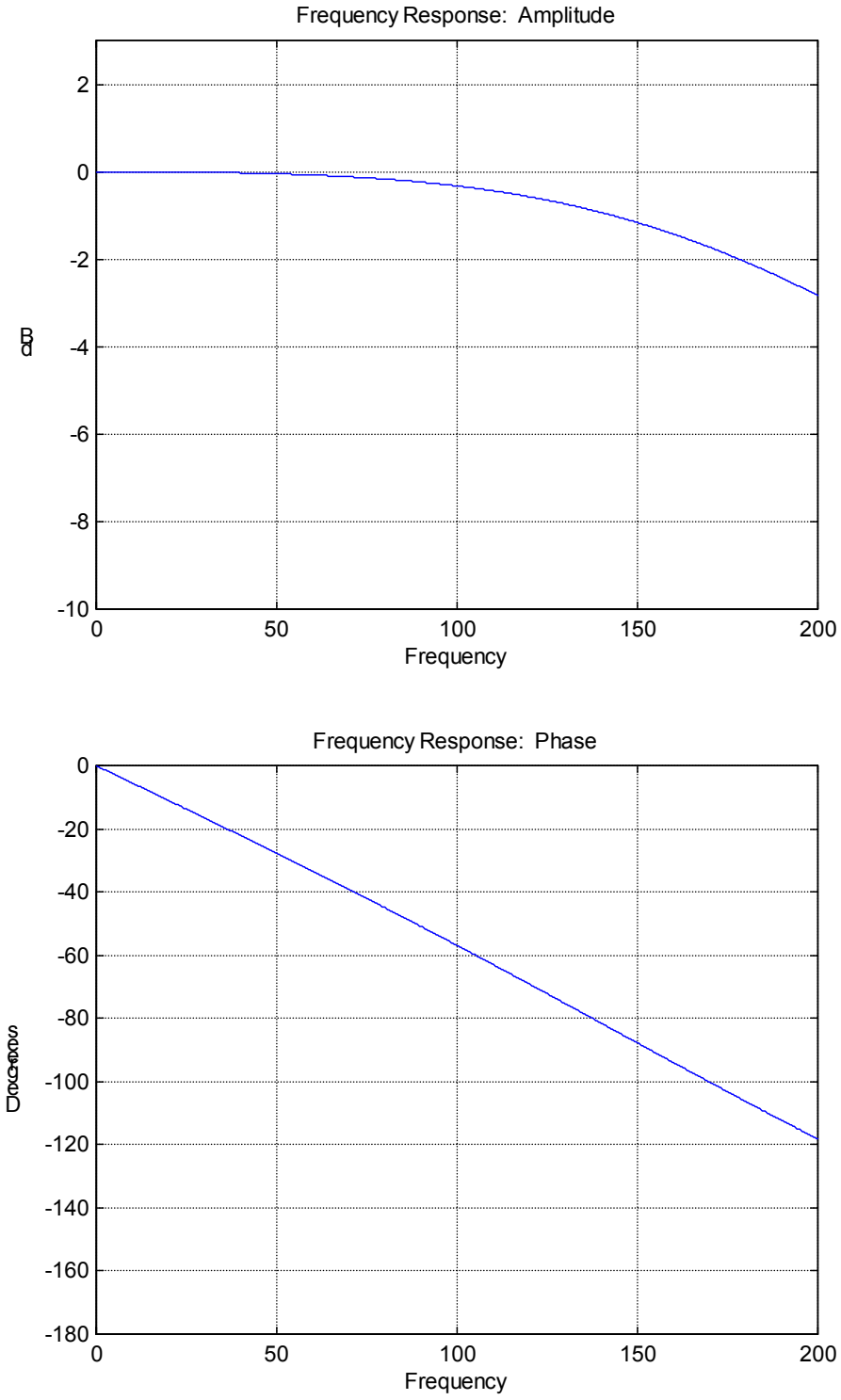
$p_4 = -3290 - 1263i$ (Pole 4)

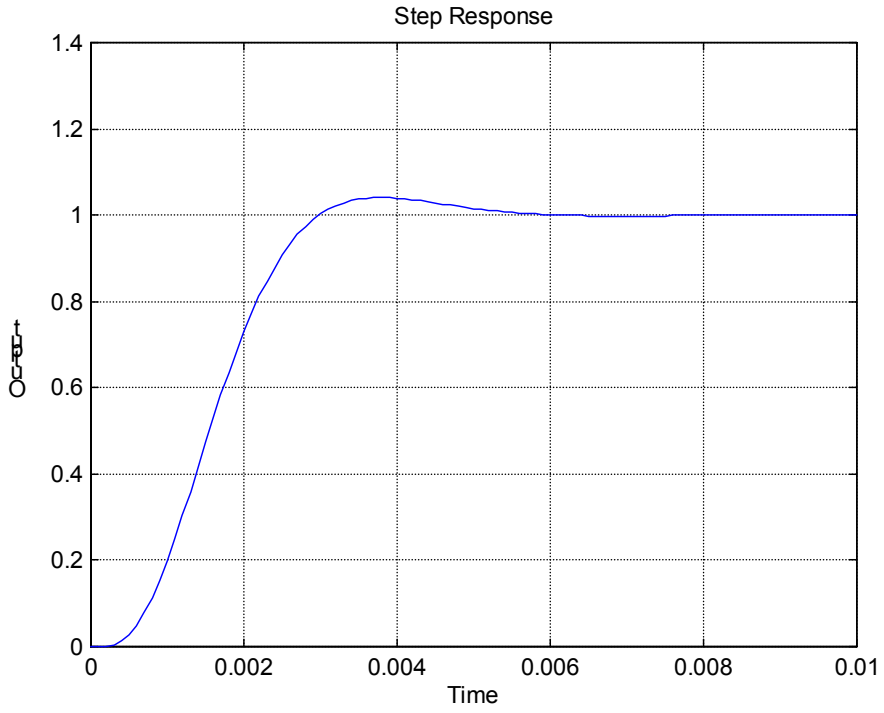
V (s) is the Laplace transform of the output voltage

A (s) is the Laplace transform of the input acceleration

A more detailed analysis of the system is available on Kinemetrics' web site. Figure 5 on the next page show the amplitude, phase and step response of this pole zero representation.

Figure 5: Amplitude, phase, and step response of the HypoSensor response model





HypoSensor Configuration

This section describes how to configure certain features of the HypoSensor by setting dual inline package (DIP) switches and jumpers on its oscillator board (P/N 110525).

These jumpers are normally configured by Kinemetrics at the time of manufacture. If your HypoSensor is set to the correct range, the following instructions for re-configuring are unnecessary.

However, if you wish to change the settings, it is possible to do so in a laboratory environment.

Kinemetrics recommends that you do not attempt to change these jumpers in the field where debris or water could get into the unit

It is possible to change the full scale range of the sensors but this requires that you completely disassemble the HypoSensor package and is therefore not recommended. These jumpers are configured by Kinemetrics at the time of manufacture. Only a trained technician can properly disassemble the HypoSensor unit. This manual contains no instructions on this procedure.

Opening the HypoSensor Case

Caution: Potential electrostatic discharge (ESD) hazard to equipment. Wear a grounded wrist strap with impedance of approximately 1 M Ω when handling the HypoSensor circuit boards to protect components from damage.

HypoSensor DIP Switch & Jumper Selectable Options

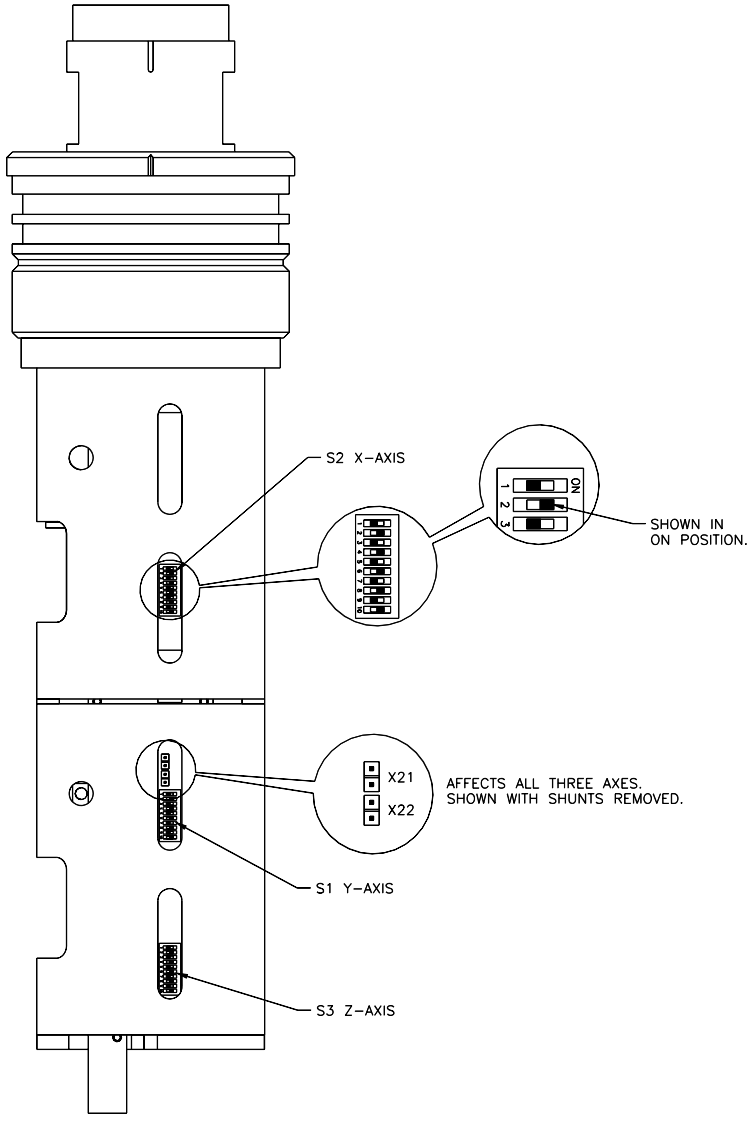
The features that are controlled by DIP switches and 2-mm jumpers are:

- Full scale output voltage level of 2.5V or 10V
- Use of low power or low noise post amplifier
- Single-ended or differential output

Access to DIP Switches

Figure 6 shows the location of the DIP switches and jumpers when the outer housing is removed. Each of the individual DIP switch sections can be placed in the *on* or *off* position as desired by using a relatively soft pointed tool such as a toothpick, cocktail stick or thin wooden stick. Please remember they are delicate. On no account should they be forced using a screwdriver or other metal tool.

Figure 6: Location of DIP switches and jumpers



Example DIP Switch and Jumper Settings

The DIP switch and jumper settings for the selectable features of the post amplifier are shown in*The HypoSensor is shipped with the two 2-mm shunt installed across X21 and X22 for the low noise amplifiers and with X21 and X22 open for the low power configuration.*

Important: If you change the configuration these jumpers must be correctly configured. X21 and X22 in for the low noise setting and out for the low power configuration.

Table 2. There are three DIP switches – S1, S2, and S3.

Each DIP switch also has 10 sections, 1-10.

- DIP switch S2 configures the X axis
- DIP switch S1 configures the Y axis, and
- DIP switch S3 configures the Z axis.

Sections 1-8 select which post amplifier is used, standard or low noise. Sections 9 and 10 set the gain of the post amplifier at 1 or 4.

X21 and X22 are 2-pin headers that apply power to the three low-noise amplifiers. These jumpers control all three axes, X, Y and Z.

The HypoSensor is shipped with the two 2-mm shunt installed across X21 and X22 for the low noise amplifiers and with X21 and X22 open for the low power configuration.

Important: If you change the configuration these jumpers must be correctly configured. X21 and X22 in for the low noise setting and out for the low power configuration.

Table 2: DIP switch and jumper settings

Switch Section S2, S1, and S3 (X, Y, and Z Axes respectively)	Single-ended ± 2.5V output Gain = 1 Low Power Post Amplifier	Single-ended ± 10V output Gain = 4 Low Power Post Amplifier	Differential ± 5V output Gain = 1 Low Noise Post Amplifier	Differential ± 20V output Gain = 4 Low Noise Post Amplifier
1	ON	ON	OFF	OFF
2	OFF	OFF	ON	ON
3	ON	ON	OFF	OFF
4	OFF	OFF	ON	ON
5	ON	ON	OFF	OFF
6	OFF	OFF	ON	ON
7	ON	ON	OFF	OFF
8	OFF	OFF	ON	ON
9	ON	OFF	ON	OFF
10	OFF	ON	OFF	ON

Jumper (all axes)				
X21	OUT	OUT	IN	IN
X22	OUT	OUT	IN	IN

Note: Differential operation of the low power amplifier is not possible.

Full Scale Voltage Output Voltages

Provides the full scale output voltages for each of the possible five full scale sensor ranges.

Table 3: Range/sensitivity calculations

Full scale range	Single-ended ± 2.5V output	Single-ended ± 10V output	Differential ± 5V output	Differential ± 20V output
1/4g	10 V/g	40 V/g	20 V/g	80 V/g
1/2g	5 V/g	20 V/g	10 V/g	40 V/g
1g	2.5 V/g	10 V/g	5 V/g	20 V/g
2g	1.25 V/g	5 V/g	2.5 V/g	10 V/g
4g	0.625 V/g	2.5 V/g	1.25 V/g	5 V/g

Voltage values above are as measured across each channel's output pins. Pins 1-2, 3-4 and 5-6 for axes X, Y, and Z respectively. Pins 1, 3, and 5 are (+) and pins 2, 4, and 6 are either (-) or ground depending on whether configured for a differential or single-ended connection to the recorder.

For best performance, a differential connection to the recorder should be used if the recorder supports differential input connections.

Factory Configured Power Supply Options

The triaxial HypoSensor is offered in two power supply configurations; the standard dual supply configuration and the optional single supply configuration. There are no user-settable features associated with the either power supply configuration.

Calibration Coil

Each HypoSensor module is equipped with a calibration coil. This coil is isolated from other HypoSensor circuitry and accurately emulates the effect of an acceleration on the system. This coil can be used to verify both the static acceleration sensitivity of the unit and the dynamic response of the system. When used with Altus recorders, the calibration signals are automatically applied to the sensor.

Direct access to the individual coils for calibration verification is not provided in the unit. They must be driven from the connector by the recorder or a similar device.

> ***Caution:*** **Damage to instrument.** When the HypoSensor is configured for single-supply operation, do not connect any power source to pin H of the connector. This pin is connected to the PGP (instrument case ground) which connects to the HypoSensor's case – if it is connected to pin H the power source will be shorted.

Power Supply

The standard HypoSensor requires a well-regulated, low-noise ±12V (± 5%) or ±15V (±5%) supply that can provide adequate current for the configuration you are using. The supply should be low-noise – less than 50 mV of ripple.

The single supply option can tolerate a relatively wide input range from 10 to 18 VDC. The supply should be low-noise and have less than 100 mV of ripple to ensure low-noise performance of the sensor.

> ***Caution:*** Incorrect power to the HypoSensor can cause incorrect readings and may damage the sensor. If the voltage is too low the HypoSensor will not attain its full-scale output and the data will be corrupted. Never supply more than +/- 15.75V to the unit and be sure the connections are the correct polarity. The HypoSensor has no protection against reversed polarity connections. Reversed power connections will severely damage the instrument!
>
> The single supply option requires 10-18V DC supplied to the positive power connection. Exceeding 18 VDC will damage the instrument as will reversing

the connections. Do not connect anything to the negative power connection terminal when using the single supply option – damage to the power supply or instrument could result. If less than 10V is applied the HypoSensor will not attain its full-scale output and the data will be corrupted.

The supply should be capable of supplying the maximum load for the sensor under operating conditions. The quiescent current is the best figure to use for sizing batteries or solar charging systems.

Table 4: Current requirements

Sensor Quiescent Current	Dual ±12V Supply	Single 12V Supply
Low-power unit	12 mA	65 mA
Unit with low low-noise amplifiers enabled	35 mA	130 mA

Sensor Full-scale Output Current	1 Axis	3 Axes
Restoring current for coils per g	2.5 mA/g	7.5 mA/g
Output amplifier load at ±2.5V single-ended or ±5V differential full-scale	0.7 mA	2.1 mA
Output amplifier load at ±10V single-ended or ±20V differential full-scale	6.6 mA	20 mA

To calculate the worst case maximum current required, take the full-scale range that the unit is set at and multiply by 7.5mA. This will give the current required to "balance" the applied acceleration.

Add to this the output amplifier load for the output you have selected.
For a dual supply add this number to the quiescent current to get the worst case current.

For a single supply option, multiply the current by 4 to account for the 50% efficiency of the DC to DC converter and voltage ratio and then add this current to the quiescent current.

The maximum current load on a dual supply for an HypoSensor set to a 2g full-scale range with a 20V differential low-noise output is calculated as below:

$$(7.5 \text{ mA} \times 2) + 20 \text{ mA} + 35 \text{ mA} = 70 \text{ mA}$$

For the single supply option:

$$((7.5 \text{ mA} \times 2) + 20 \text{ mA}) \times 4) + 130 \text{ mA} = 270 \text{ mA}$$

These values are very conservative because in normal situations all three axis of the HypoSensor are unlikely to see 2g of acceleration at the same time. Further examples are found in Table 5:

Table 5: Current requirements

Examples	Quiescent Dual ±12V Supply	Max Load Dual ±12V Supply	Quiescent Single 12V Supply	Max Load Single 12V Supply
HypoSensor 1g low-power amplifier 2.5V single-ended output	12 mA	25 mA	65 mA	104 mA
HypoSensor 2g low-noise amplifier, 20V differential output	35 mA	70 mA	130 mA	270 mA
HypoSensor 0.25g low-noise amplifier 20V differential output	35 mA	57 mA	130 mA	218 mA

Resistive Cable Loss

Calculations of the required power for a HypoSensor must account for resistive loss in the 700306 downhole cable. The two tables in this section provide the information to calculate the maximum cable length for HypoSensor units in each of the various configurations.

The standard HypoSensor requires a minimum operating voltage of 11.5V to be sure it can supply the +/-10V output with respect to ground. The standard Altus unit's power output, even in the worst case, is 11.6V.
A HypoSensor with the single supply option requires a minimum of 10 V.

The calculations for the 2g operating range are provided in the following tables. These figures are a conservative limit for all ranges other than 4g.

The following table shows the resistance and calculated voltage drop for different lengths of the 700306 cable when using three common HypoSensor configurations.

The first two columns show configurations typically used with Altus K2 data recorders. The third column shows the configuration most commonly used with non-Kinemetrics data loggers, which often require a DC/DC converter in the sensor. Be sure that the data logger uses a regulated 12V supply before using the numbers in the table.

To exceed these lengths, use a regulated power supply that supplies 15 V. Calculate the voltage drop in the cable at the maximum supply current and make sure that it meets the minimum operating voltage for the chosen configuration. Bear in mind that these figures are very conservative and assume a full 2g load on all three axes simultaneously, a situation that is extremely unlikely to occur in a borehole seismic application.

Table 6: HypoSensor cabling requirements (1 foot = 0.3048 meters)

Sensor Type	Low-power, 2g, 2.5V S/E	Low-noise, 2g, 5V differential	Low-noise, 2g, 20V differential, single supply
Sensor minimum operating voltage	10.0	10	10V
Maximum supply current	30.0	52	270mA
Minimum supply voltage	11.6	11.6	12V
Allowed cable voltage drop	1.6	1.6	2V
One-way allowed cable drop	0.8	0.8	1V
One-way allowed resistance at full-scale output	26.7	15.4	3.7 Ohms

Cable AWG	Cable Resistance per 1000 Feet	Low-power 2g, 2.5V Single-ended Maximum Cable Run in Feet	Low-noise 2g,5V Differential Maximum Cable Run in Feet	Low-noise 2g, 20V Differential, w/Single Supply Option Maximum Cable Run in Feet
20	10.90	2400	1400	330

Using Non-Kinemetrics Data Loggers

If you are using the HypoSensor with a non-Kinemetrics data logger, you must match the power, calibration and output of the HypoSensor with that of the recorder. Kinemetrics Services Group can provide help with this and can also supply conversion boxes to interface to some commonly used seismic instrumentation.

Output Voltage

The HypoSensor output is user-selectable, as is the output amplifier. Select the HypoSensor output that matches the recorder input. If possible use a differential input connection for optimum performance. Configuring the correct range and output is described earlier in this section.

The output impedance of the HypoSensor is 50 Ω to ensure the unit is stable under capacitive loading from a long cable. Normally data loggers have an input impedance of 100 kΩ or more, so the 50Ω output impedance is insignificant.

Calibration Sequence

To produce a functional test sequence the recorder must control the CAL and CCE line to the HypoSensor.

Even if the recorder cannot produce a functional test it is still very important that these lines be held at the correct potential. The CAL line is not connected to the sensor unless the CCE line is active, but to provide the best noise performance it

should not be left floating. We suggest that the CCE line be grounded to power common when the calibration coil is not in use.

The CCE line drives a transistor that operates an analog switch that connects the CAL line to the sensor module calibration coil. The transistor will turn on the analog switches at voltages between +5 to +12V. The transistor is not activated at voltages below 0.5V. This means a CMOS driver can drive the line or an open collector output pulled up to 12V.

A transistor-transistor logic (TTL) level will probably work if the sensor is close to the digitizer. *It is very important that the CCE line is not enabled when the calibration feature is not in use and that it is not powered when the unit is not powered.*

This is because the CAL line is connected to all the sensor coils during the calibration sequence, which can result in both additional noise and cross coupling between the sensors. The easiest way to prevent power conflicts from the CCE line is to connect it to the power common or the –12V supply of the unit.

To produce a functional test sequence, the data logger needs to control both the CAL and the CCE lines. The voltage applied to the CAL line should be limited to +/-10V. The sensor should reproduce any signal applied by the digitizer within the voltage limits and the bandwidth of the sensor. Thus, the calibration sequence can range from the simple pulses described below to single frequency sine waves or chirped sine signals.

Caution: Be certain that the CAL line is not active when the HypoSensor is not powered – this could damage the unit.

If the data logger cannot perform a functional test, a simple test box can be built to simulate the desired calibration sequence.

A suggested sequence is as follows:

1. Apply 0V to the CAL line
2. Turn CCE to +12V
3. Wait 2 seconds
4. Apply +2.5V to CAL for 2 seconds
5. Change CAL to <-2.5V for 2 seconds
6. Change CAL to 0V for 2 seconds
7. Turn CCE off by connecting it to 0V

This will produce a positive pulse followed by a negative pulse.

Caution: The CCE line must not be enabled during normal operation – severely degraded noise performance can result. Applying voltage to the CAL line when the unit is not powered will result in damage. Applying voltage above the power supply lines to the CAL line will also damage the unit.

Ground Loop Prevention

When the HypoSensor is used with non-Kinemetrics digitizers it is essential that the ground connections be carefully planned in order to prevent ground loops. Please see the section in this chapter on grounding.

This is especially important when using a PC-based data acquisition system. We recommend using the differential output of the HypoSensor to prevent common mode problems. When using single-ended output, the signal returns (-X, -Y, -Z) should be connected to the negative input of the analog front-end's differential or instrumentation amplifier and not to circuit common.

The common connection should return to the power supply through only one path. When using a separate mains power supply, be very careful that it does not provide a separate ground return through the AC mains ground to the data acquisition computer.

Use a star ground configuration for your system with the power supply, data acquisition system and PC all grounded at the same point.

In our experience, most noise problems with any installation are normally a result of power grounding or cable shielding!

Compass Option

The Compass option is a microprocessor-controlled fluxgate compass subsystem, consisting of a toroidal fluxgate sensing element and its associated electronics board.

The fluxgate sensor element is a saturable ring core, free floating within the cylindrical lexan housing. The purpose of the floating core is to keep the sensing element horizontal with respect to the earth. Thus, the Compass can still function with the HypoSensor package installed up to 16° away from the vertical. The sensor housing is surrounded by windings, which drive the core into saturation. Pulses whose amplitude are proportional to the sensed horizontal component of the earth's magnetic field are detected by two orthogonal secondary windings, thus providing information on the x and y horizontal components of the earth's magnetic field.

The Compass takes ten measurements consisting of 32 samples of the x and y pulses every second. These signals are converted to a DC level, digitized and then sent to a microprocessor, which uses sophisticated algorithms to translate these measurements into accurate heading information.

The Compass option can automatically adjust for hard and soft iron deviations in the HypoSensor package and the magnetic dip of its current location. Although the Compass can compensate for the magnetic material within the HypoSensor package it cannot compensate for distortions of the earth's magnetic field at the HypoSensor site. The Compass should be used away from large man-made magnetic fields such as current carrying wires and *should not* be used in steel-cased boreholes.

7. Appendix A

Table 7: HypoSensor specifications

Type	**Triaxial force balance accelerometer**
Dynamic range	155 dB + (HypoSensor noise model available from Kinemetrics)
Bandwidth	DC to 200 Hz
Calibration coil	Standard
Full-scale range	User-selectable at ± 0.25g, ± 0.5g, ± 1g, ± 2g or ± 4g
Full-scale output	Factory-selectable at: ± 2.5V single-ended; ± 10V single-ended; ± 5V, ± 20V differential
Linearity	< 1000μg /g^2
Hysteresis	< 0.1% of full scale
Cross-axis sensitivity	< 1% (including misalignment)
Zero point thermal drift	< 2% of full-scale, -20^0 to $+70^0$ C
Zero point drift	< 500μg / ^{0}C
ESD, RF, EMI protection	Double-stage transient protection with gas arrestor elements
Quiescent power consumption	12 mA from ± 12V (standard amp); 35 mA from ± 12V (low noise amp)
Operating temperature	-20^0 to $+70^0$ C (-40^0 to $+85^0$ C with reduced performance)
Housing	Stainless steel
Connector	Custom 19-pin designed to mate with KMI cable 700306; integral Kevlar stress core rated at 3,500 pounds
Dimensions	47.6 cm (18.75 inches) long x 7.62 cm (3 inches) in diameter
Pressure rating	1000 PSI
Weight	6 kg (13.25 pounds)

Table 8: HypoSensor compass option specifications

Accuracy	±0.5° (sensor level after autocal)
Repeatability	±0.2°
Resolution	0.1°
Magnetic Dip Angle	±80° range of Magnetic Dip[1]
Tilt Angle	±16°[2]
Damping	0.1 to 24 seconds, user selectable
Power Supply	8-18 VDC
Current	<40mA
Operating Temperature	-30°C +50°C[3]
Storage Temperature	-57°C +71°C
RS232 Compatible Communication	Bi-directional, 1 start, 8 data and 1 stop bit, no parity, 300-9600 Baud, user selectable
Output RS232	0 to +5V Logic Levels 10KΩ min. load
Input RS232	True RS232 Levels or 0 to +5V
Analog Output	0.1 to 1.9V (0-360°) into 20KΩ min. load

1[1] When auto-calibrated, the compass will maintain its accuracy wherever the magnetic dip is less than 80°.

[2] The compass can operate while tilted ±16° from level. Tilting within this range introduces an additional 0.3° of error.

[3]The Compass will operate without damage over the storage temperature range if the input voltage is less than 15V. Accuracy is not guaranteed beyond the stated operating temperature range.

8. Appendix B

Compass Program Command Line Communication

The commands in this section are rarely required. Only knowledgeable users should attempt to use any of these commands.

Compass Data Message Control

All checksums for compass messages (if present) are computed by XOR'ing the ASCII bytes between the dollar sign ($) and the asterisk (*). The checksum excludes the "$" and the "*". The checksum is split up into two ASCII bytes. The MSB is sent first.

Letters or numbers that are to be typed by the user appear below in bold face courier print. For example, "Type **dl** <ENTER>" – type the letters dl and press the enter key.

Enable sending current data message:

Type **s** <ENTER>

Compass response **>**

$271.8,X,YY*CHECKSUM <ENTER>**<lf>**

The compass will respond with the currently selected data message (as well as sending an acknowledgement that the message was received) which will be continuously sent at the currently selected data rate. For example, if data message 1 is selected, then the compass will respond with the message shown above.

Disable sending current data message:

Type **h** <ENTER>

Compass response: **>**

No response other than an acknowledgement will be sent.

Send data message #0 once:

Type **d0** <ENTER>

Compass response: **>**

$HCHDM,271.8,T*CHECKSUM <ENTER>**<lf>**

The compass will respond by sending an acknowledgement and data message 0, which is the NMEA 0183 format message for magnetic compass data. The NMEA message is only expressed in degrees.

The first field, HCHDM, is the standard lead-in indicating that the message is from a compass that is giving magnetic heading.

The second field, **271.8**, is the compass heading to the tenth of a degree.

The third field, **M**, is the indicator that the heading is magnetic, not true heading.

The ***** field indicates the beginning of the two byte checksum of the message.

If variation (declination) is enabled, then the NMEA message will change to the following (the "T" character is indicating true heading, not magnetic heading):

$HCHDT,271.8,T*CHECKSUM <ENTER>**<lf>**

Send data message #1 once:

Type **dl** <ENTER>

Compass response: **>**

$271.8,X,YY*CHECKSUM <ENTER>

The compass will respond by sending an acknowledgement and data message 1, which is the short heading message of "$abc.d*<**CHECKSUM**><ENTER>" where "abc.d" represents an (ASCII) format message for magnetic compass data.

The first field, **271.8**, is the compass heading to the tenth of a degree.

The second field, **X** being D if in degree mode, M if in mil mode.

The third field, **YY** being the status of the magnetic surroundings of the compass, **OL** = overload or underload condition and the data is *not valid***, OK** = that the current data is valid.

The ***** field indicates the beginning of the two byte checksum of the message.

The <CHECKSUM> includes all characters between the "$" and the "*".

This is the message type that communicates with the Kinemetrics software.

Query Commands for Serial Port

Query compass for existing data message rate:

Type **?r** <ENTER>

Compass response: **>**

?r X <ENTER>

X being:

A number representing the number of messages per minute: 6 represents a 1/10 Hz data rate, 60 represents a 1 Hz data rate, 600 represents a 10 Hz rate. **X** can be any whole number between 0 and 600.

Query compass for message type of currently output message:

Type **`?t`** <ENTER>

Compass response: **`>`**

`? tX` <ENTER>

X being:

0 = Standard NMEA 0183 message

1 = KVH version

2 = X and Y corrected output

3 = X and Y uncorrected output

> **Note**: Messages 2 and 3 are not recommended for use with the HypoSensor.

Query the compass for the status of the mil/degree flag: (i.e., is the compass data in mils or degrees?).

Type **`?I`** <ENTER>

Compass response: **`>`**

`?I X` <ENTER>

X being:

d = degrees

m = mils

> **Note**: 6400 mils = 360 degree

Send baud rate for next reset:

Type **`?b`** <ENTER>

Compass response: **`>`**

`?b X<baud rate>` <ENTER>

Send the baud rate setting for the *next* reset. Note that the reply will only tell what the EEPROM baud rate memory holds, i.e., you must already know what the current baud rate is in order to be able to communicate with the compass option.

The baud rate number, when multiplied by 100, will be the baud rate of the compass after a reset. For example, a 003 means 300 baud and 096 means 9600 baud.

When the compass is powered down and then up again (or reset with a "zap" command), the baud rate stored in the EEPROM will be used.

Set Commands for Serial Port

Set compass for data message rate:

Type **=rX** <ENTER>

Compass response: **->**

X being:

A number represents the number of messages per minute: 060 represents a 1 Hz data rate, 600 represents a 10 Hz rate. l Maximum rate of 1 Hz, minimum rate 0 Hz.

Set output message type:

Type **=tX** <ENTER>

Compass response: **>**

X being:

0 = Standard NMEA 0183 message

1 = KVH version

2 = X and Y corrected output (do not use)

3 = X and Y uncorrected output (do not use)

Note: Messages 2 and 3 are not recommended for use with the HypoSensor.

Set compass for degrees or mils:

Type **=iX** <ENTER>

Compass response: **>**

X being: The status of the mil/degree flag.

d = degrees

m = mils (do not use with HypoSensor software)

Note: 6400 mils = 360 degrees

Analog Port Query Commands

Type **?at** <ENTER>

Compass response: **>**

?at X <ENTER>

X being:

0 = Regular linear output (0.1 to 1.9 VDC)

1 = Hysteresis, linear output

2 = Sine/cosine/reference output (do not use)

Option 2 should not be used with the HypoSensor, as the necessary signal lines are not present and the compass will be placed in the wrong mode.

Analog Port Set Commands

Set compass analog output type:

Type **=atX** <ENTER>

Compass response: **>**

X being:

0 = Regular linear output (0.1 to 1.9 VDC) 5mV/° scale factor

1 = Hysteresis, linear output, 5mV/°scale factor

2 = Sine/cosine output (do not use)

Option 2 should not be used with the HypoSensor as the necessary signal lines are not present and the compass will be placed in the wrong mode.

The linear output with hysteresis has 4° of hysteresis to prevent jittering from 0.1 to 1.9V. When turning clockwise the voltage will switch at 005° from 1.925 VDC to 0.125 VDC. When turning counterclockwise the voltage will change at 001° from .105 VDC to 1.905 VDC.

Execute a warm boot (start execution from location 0):

Type **zap** <ENTER>

This command will restart the compass just like it was powered down and then back up. It will not give a hard reset to the microprocessor. Turn power off then on for a hard reset.

Query Commands

Ask the compass to report the compass serial number, software version number, hardware version number, what type of compass, calibration date.

Type **?w** <ENTER>

Compass response: **>**

?w XXXXXX,A,B,C100,99/99/*<CHECKSUM> <ENTER>

The first field, **XXXXXXX**, is the serial number of the unit.

The second field, **A**, is the software version of the unit.

The third field, **B**, is the hardware version of the unit.

The fourth field, **C100**, is the unit type.

The fifth field, **99/99/99**, is the date that the unit was calibrated at the factory (i.e., **YY,MM,DD**).

The sixth field, **<CHECKSUM>** is a 2 digit checksum of all characters up to, but not including the "*".

Query if variation (declination) is off or on:

Type **?v** <ENTER>

Compass response: **->**

?v X <ENTER>

X being:

True headings = variation is on (being used to offset compass heading).

Magnetic heading = variations off (not being used to offset compass heading).

Query the current variation (declination):

Type **?vd** <ENTER>

Compass response: **>**

?vd X <ENTER>

X being:

The declination angle in the current output mode (mils or degrees). If the compass is in degree mode the output will have a decimal point, i.e., **345.6** degrees. In mils mode the output does not have any decimal point.

Query current offset index ("A" coefficient):

Type **?vi** <ENTER>

Compass response: **>**

?vi X <ENTER>

X being:

The index ("A" coefficient offset) angle in the current output mode (mils or degrees). If the compass is in degree mode the output will have a decimal point, i.e., **345.6** degrees. In mils mode the output does not have any decimal point.

Query compass for type of damping filter used for all outputs:

Type **?dt0** <ENTER>

Compass response: **>**

?dt0 X <ENTER>

X being:

0 = Undamped

1 = Single IIR (infinite impulse response filter – RC)

2 = Sum and Dump (do not use with HypoSensor)

3 = Double IIR

> **Note**: Sum and dump filter will lead to incorrect heading data on the analog and serial output, and should not be used in the HypoSensor.

Query compass for damping time:

Type **?d0** <ENTER>

Compass response: **>**

?d0 X <ENTER>

X being:

Value from 0 through and including 9. These values are offsets into a table with the corresponding damping time:

0 = 3 seconds

1 = 4.5 seconds

2 = 6 seconds

3 = 7.5 seconds

4 = 9 seconds

5 = 12 seconds

6 = 14 seconds

7 = 16 seconds

8 = 20 seconds

9 = 24 seconds

Damping is response time to final value.

Set Commands

Set the variation (declination) on or off:

Note: The terms variation and declination are used interchangeably. Variation is the angle between True North and Magnetic North. Declination is the angle between grid north and Magnetic North.

Type **=vX** <ENTER>

Compass response: **>**

X being:

t = variation set on (correct heading with variation)

m = variation set off (do not correct heading)

Set the variation (declination) on or off:

Type **=vd,X** <ENTER>

Compass response: **>**

X being:

The variation (declination) angle must be entered in degrees. The compass must be also in the degree mode. **X** is entered to the nearest tenth of a degree (i.e., 345.0) leading zeros are optional (i.e., 045.0). Do not use negative values!

Set the offset index ("A" coefficient) to the specified value.

Type **=vi,X** <ENTER>

Compass response: **>**

X being:

The index ("A" coefficient offset) angle must be entered in degrees. The compass must be also in the degree mode). **X** is entered to the nearest tenth of a degree (i.e., 345.0) leading zeros are optional (i.e., 045.0). Do not use negative values!

Set compass for type of damping filter for all outputs:

Type **=dt0,X** <ENTER>

Compass response: **>**

X being:

0 = Undamped

1 = Single IIR

2 = Sum and Dump (do not use with HypoSensor)

3 = Double IIR

> **Note**: Sum and dump filter will lead to incorrect heading data on the analog and serial outputs and should not be used in the HypoSensor.

The single IIR damping filter is equivalent to a single section R-C low pass filter. The double IIR is equivalent to a double section RCRC low pass filter.

Set compass for damping time used for all outputs:

Type **=d0,X** <ENTER>

Compass response: **>**

X being:

0 = 3 seconds

1 = 4.5 seconds

2 = 6 seconds

3 = 7.5 seconds

4 = 9 seconds

5 = 12 seconds

6 = 14 seconds

7 = 16 seconds

8 = 20 seconds

9 = 24 seconds

The damping times are times for the output to reach its final value after a step change in heading.

Field Calibration by Terminal Mode

We recommend using Kinemetrics supplied software to perform a field calibration. These instructions are provided for users who wish to use a terminal orientated procedure.

Type **h** <ENTER> (stop continuous output)

Compass response: **>**

Type **=cel** <ENTER> Start field cal.

Compass response: **>**

$000.00 Turn compass close to 0° or to any convenient starting point

Type **=cel** <ENTER> Proceed with field cal.

Compass response: **>**

$045.0 Turn compass close to 45° or approximately 45° clockwise from the starting point.

Type **=cel** <ENTER> Proceed with field cal.

Compass response: **>**

$090.0 Turn compass close to 90° or approximately 90° clockwise from the starting point.

Type **=cel**<ENTER> Proceed with field cal.

Compass response: **->**

$135.0 Turn compass close to 135° or approximately 135° clockwise from the starting point.

Type **=cel** <ENTER> Proceed with field cal.

Compass response: **>**

$180.0 Turn compass close to 180° or approximately 180° clockwise from the starting point.

Type **=cel** <ENTER> Proceed with field cal.

Compass response: **>**

$225.0 Turn compass close to 225° or approximately 225° clockwise from the starting point.

Type **=cel** <ENTER> Proceed with field cal.

Compass response: **>**

$270.0 Turn compass close to 270° or approximately 270° clockwise from the starting point.

Type **4=cel** <ENTER> Proceed with field cal.

Compass response: **>**

$315.0 Turn compass close to 315° or approximately 315° clockwise from the starting point.

Type **=cel** <ENTER> Proceed with field cal.

Compass response: **>**

Field calibration complete

Noise score: X where X is between 1 and calibration count 00.